THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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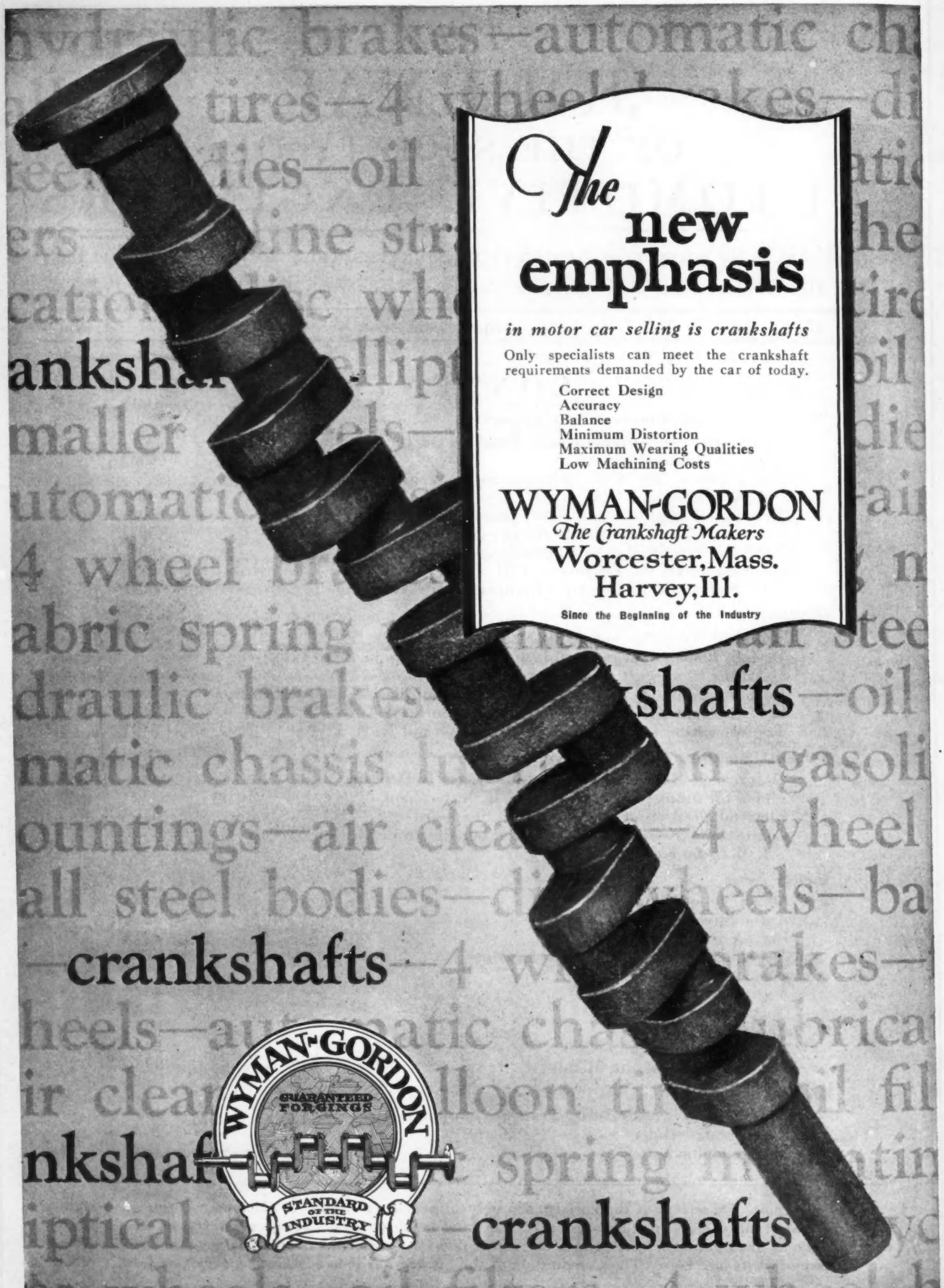
Vol. XX April, 1927 No. 4

CONTENTS

The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XX April, 1927 No. 4

Chronicle and Comment

All-Ohio S.A.E. Day

AT the March 21 meeting of the Cleveland Section, H. L. Cannell, chairman of the Ohio State University Student Group invited the members of the Cleveland Section to attend the All-Ohio S.A.E. Day at the Ohio State University on May 14. The Student Group will act as host to the members of both the Cleveland and the Dayton Section and to other Society members who find it possible to attend.

Section Stunts

THE Summer Meeting owes much of its appeal to the novel stunts sponsored by the Sections of the Society. Everyone recalling the Summer Meeting last year at French Lick Springs will remember the impertinent headwaiter and the other events engineered by the Sections.

This year many new ideas are being worked on and the members may expect a large amount of amusement not included in the official program.

The Engineer of the Future

AT the Chicago Section Meeting in March F. E. Moskovics talked on the subject, The Engineering Stage of the Automobile Industry Has Arrived. According to Mr. Moskovics, the real engineer of the future must be a creative artist, an executive and an engineer. His talk, reported on p. 434, should be read by every member of the Society as it applies to practically all phases of automotive engineering and merchandising.

Materials Conference in Germany

IN October a conference on engineering materials will be held in Berlin. This is being planned by the Society of German Engineers, in cooperation with the Society of German Metallurgists, the German Society for the Science of Metals, and the German Federation for Testing Engineering Materials. A large number of papers will be read at the Charlottenburg Institute of Technology and a demonstration of testing materials will be made in connection with an exhibition in the new Automobile Hall at Kaiserdamm.

Members who are interested in preparing papers for presentation at the conference are asked to communicate with the Society's office in New York City. Suggestions for papers indicating the names of the authors and subjects, together with brief statement of proposed contents, will be transmitted to the committee on papers in Germany. The presentation of a paper should not require more than 30 min.

Weeks Transportation Committee Chairman

PAUL WEEKS, of the American Car & Foundry Motors Co., has been appointed chairman of the National Transportation and Service Meeting Subcommittee. The meeting will be held in Chicago early in November. The program for the technical sessions and inspection trips is now being planned. Suggestions as to subjects that should be covered at the technical sessions, as well as to authors, will be appreciated.

The 1927 Summer Meeting

PLANS for the Summer Meeting at French Lick Springs are now taking final form and the complete program for the technical sessions and the sports events will appear in an early issue of *The Meetings Bulletin.*

Special trains are being arranged by the Chicago, Detroit and Metropolitan Sections, and special cars carrying members from other Sections will be attached to the special trains en route.

The preliminary announcement of the 1927 Summer Meeting will be found on p. 426.

Detroit Production Meeting

SIX interesting sessions and a dinner have been arranged in connection with the annual meeting of the Production Executives' Division of the American Management Association in Detroit on April 27 to 29 at the Book-Cadillac Hotel. The management Division of the American Society of Mechanical Engineers and the Detroit Section of the Society of Automotive Engineers are cooperating in the meeting. The complete program for the meeting will be sent to the members of the Detroit and the Cleveland Sections. A resume of the program will be found on p. 425.

Denver S.A.E. Club Organized

MEMBERS of the Society in Denver, have organized the Denver S.A.E. Club, the first meeting of which was held in connection with the Automobile Show on Feb. 16. E. F. Harrison, of the Harrison Motor Car

Co., Inc., was appointed chairman and Vernon Peterson, of the Mountain States Re-Grinders' Association, was appointed secretary.

The purpose of the Club is to give the Society members in Denver and Colorado Springs an opportunity to discuss matters of interest, not enough members being located in these two cities to make possible the organization of a Section of the Society.

National Production-Meeting Plans

AT the January meeting of the Meetings Committee, the week of Sept. 19 was decided upon for the National Production Meeting, but with regard to whether the meeting should be held in Detroit or Cleveland, it was thought that the Production Advisory Committee should study the question and advise the Meetings Committee.

At a meeting of the Production Advisory Committee in Cleveland on March 21, the situation was discussed at length and the decision reached that it is advisable that the first 2 days of the National Production Meeting be held in Cleveland and the last 2 days in Detroit, a boat trip, during which an entertainment could be held, to be arranged to carry the members from Cleveland to Detroit. This recommendation was accordingly referred to the Meetings Committee and will be acted upon shortly by mail vote.

The proposed arrangements will make it possible for Detroit members to attend the exhibition of the National Machine-Tool Builders' Association in Cleveland during the Cleveland technical sessions of the Production Meeting and for the Cleveland members to visit the exhibition of the American Society for Steel Treating in Detroit at the time of the Detroit sessions. Inspection trips will be arranged in both Detroit and Cleveland.

Shimmy Mathematically Analyzed

AT least two discussers at the Chassis Session of the Annual Meeting agreed as to the fundamentals underlying shimmy. One of these W. R. Griswold, of the Packard Motor Car Co., said:

> A peculiar thing about the shimmy problem is that the gyroscopic forces are not primary exciting forces but are produced as a secondary exciting force due to some other primary exciting force. The primary exciting forces may be sufficient to overcome the friction in the steering-mechanism and thereby give rise to the growth of the gyroscopic force, which may do one of two things or both, depending on conditions; start a wheel wabble accompanied by some evidence of radiator shimmy, or start a tramping or radiator shimmy accompanied by wheel wabble.

Prof. H. A. Huebotter expounded a gyroscopic theory of shimmy in agreement with that of Mr. Griswold and promised to make the mathematical deductions implied in the theory for the benefit of those interested. The analysis furnished by Professor Huebotter in accordance with this assurance appears in Automotive Research of this issue of THE JOURNAL. Professor Huebotter presents this analysis with no claim that it is a cure-all for shimmy, but rather with the hope that it will be the basis of a new line of investigation of this phenomenon.

Operation and Maintenance

FOR the purpose of providing timely and valuable information for members engaged in the operation and maintenance of motor-vehicle fleets, and to foster industrial and public interests, it has been proposed that a section of THE JOURNAL be devoted to topics of interest in this connection. The Operation and Maintenance Committee, under the chairmanship of R. E. Plimpton, will cooperate in the conduct of this section. Members are requested to suggest subjects for discussion.

The Operation and Maintenance Committee is establishing relations with other organizations interested in its work, which relates in general to engineering features of large-scale handling of motor-vehicles. As announced in the March issue of THE JOURNAL, the members of the Committee are at work in all parts of the Country. To make its procedure effective, the Committee has been divided into a number of Subcommittees according to the classes of subjects that are to be taken up. A Pacific-Coast Subcommittee has been organized. All the members of the main Committee have been assigned to one or more Subcommittees. The Subcommittee on Accounting held a session in New York City last month to consider association standardization of accounts, particularly with respect to operation and other costs of motor-vehicles, and with the purpose of comparing and analyzing facts.

The Committee has before it a task that is fundamental and of a pioneer nature in various ways, including recommendations as to nomenclature, which is of course related closely to cost keeping as well as other vital features. The activities of the Committee will be inherently educational, and accordingly very helpful in the basic and rapidly expanding engineering field of fleet operation and maintenance.

A Stage in Detonation Study

IN every scientific study a period arrives when progress is furthered as much by contemplation as by activity. Then, from the mass of facts that have been ascertained, the theories that have been propounded and the generalizations that have been drawn, those that have been frequently confirmed can be sorted and arranged to point, even if roughly, toward the goal that recedes alike before philosopher and scientist, the truth. This stage represents a plateau, arrived at by many different paths by many different travelers, from which can be surveyed the progress made and the heights still to be scaled.

That the study of detonation has reached this momentary stopping-place seems to be indicated by the nearly simultaneous appearance in this Country and abroad of two publications in the contemplative mood. In Automotive Research in the March issue of THE JOURNAL appeared a brief summary of what was thought to be the commonly accepted postulates concerning detonation. This statement was prepared by the Society's Research Subcommittee on the Causes and Effects of Detonation. The February issue of the *Automobile Engineer* marked the initiation of a series of articles on detonation in which the author proposes to:

> Coordinate and simplify what is known upon the subject and, by filling in some gaps regarding gaseous combustion, make it possible to get down to the fundamental cause of detonation with its dual characteristics of temperature production (in time) and propagation (in space).

A more detailed account of the nature and extent of the latter treatise is given in the Notes and Reviews columns of this issue of THE JOURNAL. Such surveys provide for the investigator a new starting-place, and, for the interested but less informed reader, a general background of information. Encouragement is forthcoming from such progress in the study of a subject presenting so many obstacles as does that of detonation, in view of the many factors involved and also of the difficulty of observing the phenomenon subject to the conditions under which it normally occurs.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

MECHANICS OF FRONT-WHEEL SHIMMY

Gyroscopic Theory Explains How Shimmy Starts and Why It Continues

Those who were so fortunate as to attend the Chassis Session at the Annual Meeting will recognize in Fig. 1 a diagrammatic representation of the simple apparatus with which Prof. H. A. Huebotter[1] demonstrated the gyroscopic effects entering into the now ever-present but still little-understood phenomena of "shimmy." Professor Huebotter starts with the rather generally accepted assumption that axle "tramping" precedes shimmy.

Using a model that is essentially a plain gyroscope mounted in the same way that a front wheel is mounted on the axle, Professor Huebotter illustrated the gyroscopic theory by starting the disc, or wheel, spinning at a fairly high rate of speed in a clockwise or forward direction. Then, assuming that the disc represented a right front-wheel and that the observer was in the driver's seat so that he viewed the axle from the rear and the steering pivot from above and further considering clockwise rotation as positive, Professor Huebotter showed that a negative rotation of the axle as upward motion of its outer end caused the knuckle to steer to the left. Likewise a positive rotation of the axle produced a turn of the steering-knuckle to the right. Thus, a continuation of a combination of the two axle-motions, that is, an up-and-down motion as in "tramping" caused a steering-knuckle movement or precession identical with that of "shimmy."

In pointing out the various factors that contributed to this precession, attention was called to the fact that the relations between angular acceleration, precession and velocity could all be determined mathematically. These mathematical deductions Professor Huebotter promised to make for the benefit of those who might be interested and we are pleased to present them here while the memory of the demonstration to which they apply is still fresh in the minds of many.

However, up to this time it has been impossible to have an independent check made on the work. Comments or criticisms from the viewpoint of the mathematical physicist will be appreciated by Professor Huebotter who hopes that this contribution will serve as an incentive for a new line of experimentation on front-wheel shimmy.

Professor Huebotter's Analysis

The question of the hour in chassis design is "Why do front axles tramp and front wheels shimmy?" Why shouldn't they? The conditions are ideal for both phenomena which are, in fact, mutually dependent. Granted that road conditions; incorrect steering-gear geometry; tire unbalance; low tire-pressure; spring flexibility; wheel pitch, toe-in and caster; axle weight; wheel inertia; and spring mounting are all pertinent factors in the shimmy problem, the fact remains that the rotation of the wheels and the freedom of the axle to oscillate are in themselves sufficient causes for shimmying. It is true that the vibratory forces induced by these two actions may have such high frequency that they lack the necessary time and amplitude to function properly or they may be damped out by certain devices, but they exist, nevertheless, as the following analysis will show.

A front wheel has all the properties of a gyrostat and, when traveling at high speed, sets up gyrostatic forces. Mounted on the steering-knuckle, it is free to rotate about five axes—its own horizontal spindle, the vertical steering-pin, the horizontal spring-anchor bolts, and imaginary vertical and horizontal axes at the middle of the axle bed.

Two Applicable Gyroscopic Properties

A few experiments with a gyroscope will demonstrate two facts.

(1) If the rotor is spinning rapidly about its own axle, a torque applied to the frame about an axis normal to the axle will cause the whole assembly to rotate in a direction which, if continued for 90 deg., would bring the wheel axle parallel to the torque axis, and the rotation of the wheel in the same direction as the applied torque. This induced motion, normal to both the axle and the applied turning-force, is called precession

(2) Now if another torque is also applied to the frame in the direction of precession, the gyroscope will move in opposition to the original force, as could have been predicted from the first result. These two properties of the gyroscope seem adequate to explain why axles tramp and wheels shimmy

The behavior of the front axle and wheels is, of course, much more erratic than that of the ordinary gyroscope. Instead of uniform rotor-velocity and uniform frame-torques, the axle assembly is under the action of vibratory forces and accelerating or decelerating wheel-velocities which induce gyrostatic forces of exceptional violence.

No attempt will be made to analyze the shimmy problem in all its details. A condition only one step more complicated than that of the simple gyroscope will be discussed here, but it is believed that the conclusions will be definite enough to show how shimmy starts and why it continues.

Derivation of Equations

A conventional left front-wheel, steering-knuckle and axle bed are shown in Fig. 1, with the geometrical equivalent in

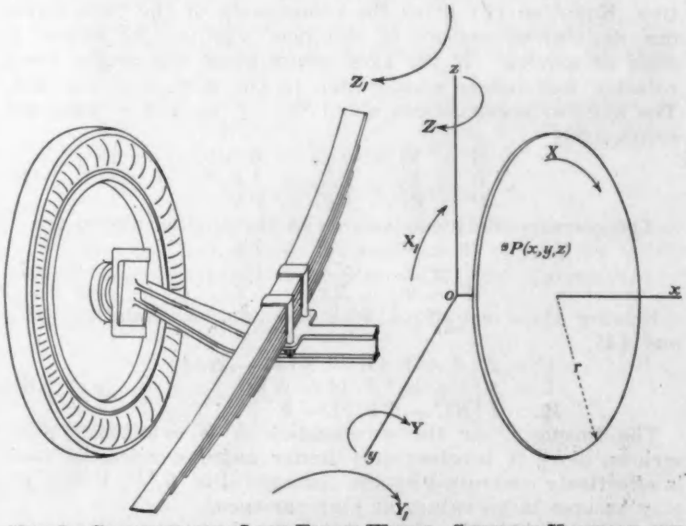


FIG. 1—CONVENTIONAL LEFT-FRONT WHEEL, STEERING-KNUCKLE AND AXLE-BED, WITH GEOMETRICAL EQUIVALENT IN PLACE OF RIGHT-END ASSEMBLY

The Spindle of the Rotor Is the ox Axis, the Steering Pivot Is the oz Axis and the Normal to the xz Plane Is the oy Axis of the Rectangular Coordinate System to Which the Rotor Is Referred

[1] M.S.A.E.—Associate professor of automotive engineering, Purdue University, Lafayette, Ind.

place of the right end-assembly. The following notation will be adopted. The rotor is referred to a rectangular coordinate system of which its spindle is the *ox* axis, the steering pivot is the *oz* axis, and the normal to the *xz* plane is the *oy* axis. Angular velocities are positive if they have a clockwise direction when viewed from the right, the top, or the rear, as indicated by the arrows. Angular accelerations are positive when angular velocities are increasing in the positive direction.

Let X, Y and Z represent the angular velocities and R, S and T the corresponding angular momenta of the rotor about the *ox*, *oy* and *oz* axes; and let X_1, Y_1 and Z_1 indicate the angular velocities of the whole coordinate system or the front-axle assembly about the origin *o*.

This notation is general and provides for every conceivable direction of rotation in space. In the automobile problem, X represents wheel velocity due to the motion of the car, and Z is the rate at which the steering-knuckles rotate about their pivots. Since the front axle is made rigid vertically to withstand the weight of the chassis, the wheel can rotate in the *xz* plane only in company with the axle bed; so $Y = Y_1$. The vertical oscillation X_1 of the axle about the spring anchor-bolts and the horizontal oscillation Z_1 due to unequal deflections of the springs are inherent properties of the spring design.

The linear velocity components of any point P (x, y, z) on the disc parallel to the *ox*, *oy* and *oz* axes with reference to the origin *o* are respectively

$$\left.\begin{aligned} dx/dt &= x_2 = Yz - Zy \\ dy/dt &= y_2 = Zx - Xz \\ dz/dt &= z_2 = Xy - Yx \end{aligned}\right\} \qquad (1)$$

The angular momentum of the disc about the *ox* axis is

$$R = \Sigma m(z_2 y - y_2 z)$$

where m is the mass of the elementary volume at P. Replacing the velocity components z_2 and y_2 by their equivalents in Equation (1) and repeating the operations with S and T, we have

$$\left.\begin{aligned} R &= X\Sigma m(y^2 + z^2) - Y\Sigma mxy - Z\Sigma mxz \\ S &= Y\Sigma m(x^2 + z^2) - X\Sigma mxy - Z\Sigma myz \\ T &= Z\Sigma m(x^2 + y^2) - X\Sigma mxz - Y\Sigma myz \end{aligned}\right\} \qquad (2)$$

Since the disc is symmetrical about each of the three axes, the products of inertia, such as Σmxy, vanish. Let J denote the moment of inertia $\Sigma m(y^2 + z^2)$ about the *ox* axis, and I the moments of inertia $\Sigma m(x^2 + z^2)$ and $\Sigma m(x^2 + y^2)$ about the *oy* and the *oz* axes which are equal. The ratio of I to J, being governed by the ratio of x to r, is constant and may be represented by K so that $I = KJ$. The expressions for the angular momenta, then, reduce to

$$\left.\begin{aligned} R &= JX \\ S &= KJY \\ T &= KJZ \end{aligned}\right\} \leftarrow h_1 = A\omega_1 \qquad (3)$$

If the *ox*, *oy* and *oz* axes preserve their original orientation, Equation (3) gives the components of the instantaneous angular-momentum of the disc whether the origin is fixed or moving. If the axes rotate about the origin, their rotation will induce acceleration in the motion of the disc. The angular accelerations about the *ox*, *oy* and *oz* axes are respectively

$\alpha = \dot{\omega}_1 - \omega_2\theta_3 + \omega_3\theta_2$

$$\left.\begin{aligned} A &= X_2 - YZ_1 + ZY_1 \\ B &= Y_2 - ZX_1 + XZ_1 \\ C &= Z_2 - XY_1 + YX_1 \end{aligned}\right\} \qquad (4)$$

The corresponding components of the applied torque are

$$L \quad \left.\begin{aligned} U &= R_2 - SZ_1 + TY_1 \\ V &= S_2 - TX_1 + RZ_1 \\ W &= T_2 - RY_1 + SX_1 \end{aligned}\right\} = \dot{h}_1 - h_2\theta_3 + h_3\theta_2 \qquad (5)$$

Solving these equations with the help of Equations (3) and (4),

$$\left.\begin{aligned} U &= J\,[A + Y\,(Z_1 - Z)\,(1 - K)] \\ V &= J\,[KB + XZ_1\,(1 - K)] \\ W &= J\,[KC - XY\,(1 - K)] \end{aligned}\right\} \qquad (6)$$

The torque U or the acceleration A is evidently never serious, since it involves only minor angular velocities and is effectively controlled by the springs. But B, C, V and W may assume large values at high car-speed.

Let us consider the simplest relation between axle tramping and wheel shimmying. If the steering mechanism were reversible and frictionless, W would vanish, whence

$$C = [(1 - K)/K]\,XY \qquad (7)$$

Equations (5) are sufficient

When the car is moving forward and the axle is tramping with the right end on the downward swing, both front wheels will steer toward the right. On the rebound of the axle they will steer toward the left. The necessary and sufficient condition for high-speed shimmy, then, is a tramping axle.

Practical Application

Tramping can obviously be started by a bump in the road under one wheel; but it can also be induced on a smooth, level surface. Suppose the hand steering-wheel is suddenly turned toward the right when the car is traveling at high speed. The tie-rod will exert a positive torque W about the steering pivot which, as shown by Equation (6), may produce both the positive acceleration C about the *oz* axis and the negative rotation $-Y$ about the *oy* axis. If there is no constraint in the system, both results will occur; the right end of the axle will rise while the wheels turn toward the right. If the further precession of the wheels toward the right on the rebound of the axle does not upset the car, the shimmy will continue.

It is evident that many factors besides those considered in the foregoing take part in the shimmy and thereby modify the results. We have not considered the distortion in the front springs, the tires and the steering-gear, all of which alternately absorb and release energy while shimmying. A brief analysis of a shimmy cycle will show qualitatively the effects of these parts.

Suppose the right front-wheel to have just encountered a bump while traveling at high speed. The right end of the axle suddenly rises in opposition to the spring, which deflects, stops the axle and acquires potential energy at the expense of the kinetic energy of the axle. The spring immediately reacts, swinging the right wheel downward, Y being positive, about some instantaneous center near the middle of the axle bed. The spring torque, besides accelerating the axle, induces precession of the wheel toward the right, and the ensuing high angular-velocity of the axle causes the precession to continue after the energy of the spring has been expended. But the rapid twisting of the wheel about the steering pivot distorts both the steering-mechanism and the tire walls until a resisting torque is built up of sufficient magnitude to stop the precession. As soon as the axle passes its normal position it begins to decelerate. This permits the steering-gear and the tire walls to resume their unstrained state and so the wheel returns to its straightforward position. But since the wheel is rotating about the steering pivot in a negative direction under the influence of a negative torque, the axle must precess downward, that is, in the direction in which it is already moving, until stopped by the spring. Further turning of the wheel toward the left follows, as a consequence of both the angular momentum of the wheel about the pivot and the precession induced by the negative rotation of the axle.

The combination of the gyrostatic forces of the wheels and the resilience of the springs, the tires and the steering-mechanism seems to cause axle assembly and the steering-knuckles to oscillate alternately. The wheels turn toward the right when the axle is at the top of its swing and toward the left when at the bottom. When the axle is moving most rapidly, at the center of its path, the wheels are in one of their extreme positions at the right or the left.

A question arises as to the reason for the persistence of shimmy after it has begun. Why does not the internal friction of the axle and spring assembly damp out the shimmy? Remembering that any force which tends to increase the velocity of wheel precession will react against the motion of the axle bed which causes that precession, we have a clue to the force that nullifies the damping.

Suppose the right end of the axle to be at the midpoint of its upward swing. Then X is positive, Y is maximum negatively, Z is practically zero, and the negative acceleration $-C$ is stopped by the rigidity of the tires and the steering-gear. But the resiliency of these members sends the wheels back through their normal position and into a right turn by the time the axle is at the top of its travel.

During this quarter of the cycle the only external forces acting on the system were those arising from the elastic deformation of the various parts. But just as the axle is ready to begin its downward motion another force comes into play which raises the axle still higher. So long as the front wheels are pointing in the direction of the car motion, their angular velocity is uniform for a constant car-speed. If they retained the same angular velocity while precessing toward the right, the forward component of the car speed would be reduced. The large ratio of car momentum to wheel angular-momentum, however, shows that the wheels must either accelerate or slide as they precess. Their motion is probably a combination of both, but it is evident that the acceleration is trying to hurry the precession and that the axle will therefore receive an external upward-force at the time the negative rotation $-Y$ is about to stop. If this force is great enough to overcome the frictional damping-effects in the system, shimmying will continue. The fact that a large tractive effort is required to accelerate the front wheels explains why shimmy does not occur on a slippery surface.

Factors That May Reduce Shimmy

It is apparent from the foregoing discussion that two things are essential for shimmy

(1) Vertical oscillation of the front axle or tramping
(2) Sufficient amplitude of tramping and of precession to accelerate the angular rotation of the front wheels

Anything that will reduce these factors should relieve the shimmy. High tire-pressure, a light-weight axle assembly and stiff front-springs prevented shimmy in the earlier cars. Springs of unequal flexibility and widely separated spring-pads on the axle should break up and reduce the angular oscillations of the axle in spite of the other contributing causes of shimmy.

But the most logical method of eliminating shimmy seems to lie in abolishing the axle bed and in mounting the steering-pivot guides on the chassis frame. This construction will reduce the angular movement of the wheel spindles in the vertical plane and, with proper spring-suspension, will leave only the steering-knuckles and the wheels unsprung.

DETROIT PRODUCTION MEETING

THE annual meeting of the Production Executive's Division of the American Management Association will be held this year in Detroit from April 27 to 29 inclusive in the Italian Room at the Book-Cadillac Hotel. The Management Division of the American Society of Mechanical Engineers and the Detroit Section of the Society of Automotive Engineers are cooperating in the meeting.

All of the papers at the meeting will be on the general subject of controlling avoidable manufacturing expenditures. Many of the papers included are of special interest to members of the Society interested in production. The complete program follows:

April 27

Morning Session

Control Points in Manufacturing Expenditures, by Oscar Grothe, vice-president, White Sewing Machine Corporation

Procedure for Locating Causes of Unnecessary Expenditures and for Indicating the Executive Action for Their Control, by Wallace Clark, consulting management engineer

Afternoon Session

A Purchasing Schedule That Abolished Storerooms, by Carl J. Sherer, treasurer, Marmon Motor Car Co.

Stores Control of Raw Materials, by J. E. Padgett, assistant to general superintendent, Spicer Mfg. Corporation

Evening Session

Quality Inspection of Materials, by L. I. Shaw, development engineer, manufacturing organization, Western Electric Co., Inc.

April 28

Morning Session

Planning and Controlling Work in Process in Belden Mfg. Co., by Charles S. Craigmile, assistant general superintendent

Planning and Controlling Work in Process in Dayton Steel Foundry Co., by J. D. Towne, industrial engineer

Afternoon Session

Reduction of Costs of Production through Reduction or Elimination of Accidents Usually Classed as Avoidable, by L. P. Alford, editor, *Manufacturing Industries*

Production Control in the Perfection Stove Co., by Charles G. Rehmer, production manager

Dinner

C. F. Kettering, general director, General Motors Corporation Research Laboratories, presiding

Some Observations on Industrial Conditions in Russia, by Frank J. Tone, president, Carborundum Co.

Address by Alexander Dow, president, Detroit Edison Co.

April 29

Morning Session

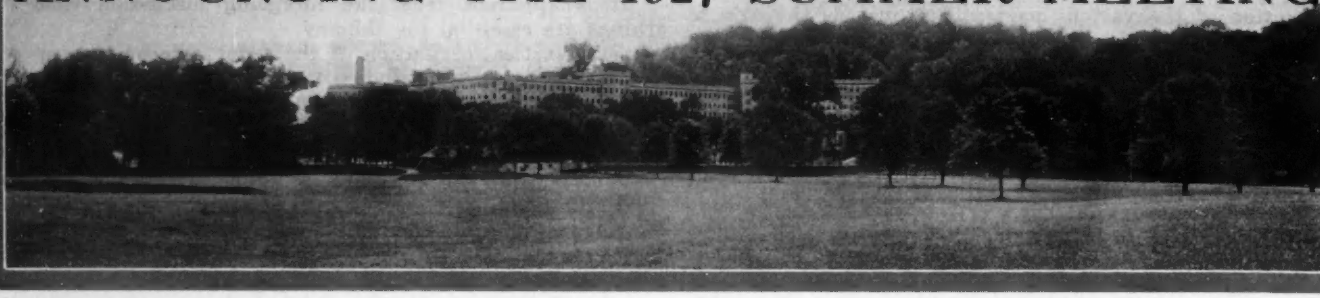
Reducing Production Costs through Training Old and New Workers, by W. S. Berry, director of training, Scovill Mfg. Co.

Controlling Avoidable Manufacturing Expenditures during a Change in Design, by E. E. Vender, manager, Systems Staff, Ernst & Ernst

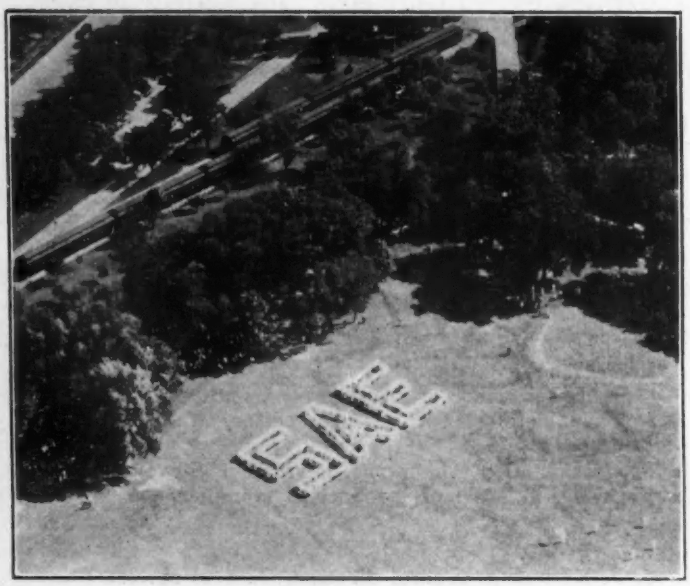
Afternoon Session

Controlling Avoidable Manufacturing Expenditures during an Increase or Decrease in Output, by H. G. Perkins, industrial engineer, Chrysler Corporation

ANNOUNCING THE 1927 SUMMER MEETING



On the morning of Wednesday, May 25, the S.A.E. special trains from New York City, Chicago and Detroit will roll into the sidings in front of the French Lick Springs Hotel for the second Summer Meeting at French Lick Springs.



THE AIRPLANE PHOTOGRAPH OF 1926

The program for the 4 following days, Wednesday to Saturday inclusive, is now being arranged by the Meetings Committee and promises technical papers and sports that will keep everyone extremely busy during the entire 4-day meeting.

The outstanding event of the Summer Meeting will be a Sections contest that will be absolutely novel. It will take place on the lawn in front of the veranda where everyone will have an opportunity of seeing the entire contest. The Meetings Committee is not sure whether it will turn out to be a three-ring circus or a speedway classic, but no matter what happens it will be of as much interest to the spectators as to the participants. The final plans will be announced at the April Sections Meetings and in the May issue of THE JOURNAL.

THE TECHNICAL SESSIONS

To determine the subjects of particular interest to the members at this time, a questionnaire listing the various subjects that were thought to be of interest was sent to a representative list of members. The returns indicate that the subject of Four-Speed Transmissions is of the most general interest, other important subjects being Brakes, Headlighting, Riding Qualities, The Car of 1937, Superchargers, High-Speed versus Low-Speed Engines, Lubricants, Fuels, Shock-Absorbers, Shimmy, and Research.

One entire session will be devoted to a discussion of four-speed transmissions. S. O. White, of the Warner Gear Co., will present the only paper at this session and the discussion will be followed by a demonstration of passenger cars equipped with different types of four-speed transmission. Brakes will also be the subject of another session. Papers on internal brakes, non-ferrous metal alloy brake materials, brake-lining testing, and brake testing and adjusting have been accepted by the Meetings Committee.

To allow sufficient time for the discussion of the papers dealing with engine design, two engine sessions are being

A GLIMPSE OF THE WOODS SURROUNDING FRENCH LICK SPRINGS HOTEL

planned. The first will be devoted to the discussion of passenger-car superchargers and aluminum pistons. The paper on superchargers will be given by David Gregg, of the A. C. Spark Plug Co., who has made an extensive study of the application of superchargers to passenger-car engines. Mr. Gregg will exhibit two cars at the Summer Meeting equipped with superchargers. At the second engine session, papers will be presented on valve-spring surge, road failures of electrical apparatus and timing-chain design. All of these questions are of particular importance at this time. The paper on valve-spring surge by W. T. Donkin and H. H. Clark, of the Cleveland Wire Spring Co., indicates that the stress in poppet-spring valves may possibly be as much as twice the estimated stress under certain operating conditions owing to surging or shimmy. High-speed motion pictures will be shown of poppet-valve springs working under various conditions. D. P. Cartwright, of the North East Electric Co., will present the paper on servicing of electrical apparatus, which should be of extreme value to designers of electrical apparatus and to engineers specifying electrical equipment. The paper will cover the relative percentage of failures of different units of the electrical system and the reasons therefor.

One session will be devoted to a debate on high-speed versus low-speed engines. Each side will be supported by three members. Thirty minutes will be allowed each side to present their case and 30 min. for rebuttal. 10 min. to be allocated to each man for presentation and rebuttal.

At the Research Session, R. E. Carlson, of the Edison Lamp Works, will present data showing the effect of fog and wet roads and head-lamp lenses on road illumination. Dr. M. R. Schmidt, of the Standard Oil Co. of Indiana, will submit specifications for petroleum lubricants which may serve as a basis for standard specifications.

A. E. Northup, of the Murray Body Corporation, will present a blackboard talk on body design with special reference to body moldings and cheat-lines. Owing to the extreme interest in body design at this time, Mr. Northup's paper should prove of tremendous interest to every car engineer. The effect of legislation on design and automotive equipment will be covered by D. C. Fenner, of the International Motor Co.

Sports Events

Over 200 players entered the qualifying rounds of the S.A.E. Golf Tournament last year. This year it is expected that golf will continue to be the leading sport and that both the Hill Course and the Lower Course will be well traveled by the great majority of the Society members.

Trap-shooting will also attract its large number of enthusiasts, A. J. MacDowell having agreed to take charge of the trap-shooting again. Guns will be available for those who do not wish to bring their own and for such members who desire to try their hand at this sport for the first time.

The usual tennis and horseshoe-pitching tournaments will be held as well as the field and track events.

The Meetings Committee is planning several unusual events for the ladies.

The Formal Gardens

Where a Short Drive or a Hook Means Trouble

One of the Several Springs

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S.A.E. Standards Committee and other standards activities are reviewed herein

METRIC THRUST BALL BEARINGS

Subdivision of Ball and Roller Bearings Division Develops Proposals

One of the difficult problems that has been before both the Ball and Roller Bearings Division of the Society's Standards Committee and the Ball Bearing Sectional Committee sponsored by the Society and the American Society of Mechanical Engineers under American Engineering Standards Committee procedure has been the developing of revised tables of thrust ball bearing dimensions. Efforts are being made to formulate standards of an international character along the same lines that has practically been accomplished for the annular type of ball bearing. Consideration has been given to the use of thrust bearings in machine tools and other types of machinery that are exported to a considerable extent, as well as to their limited use in motor-vehicles, particularly in connection with prompt and economical servicing of such apparatus abroad. The problem of standardization has been a difficult one but the Subdivision feels that it begins to see possibilities of its accomplishment at this time in connection particularly with the single-direction flat type of bearings in the medium and heavy series. It is hoped that after these standards have been worked out they will serve as the basis for standardization of the double-direction flat type and the single-direction spherical type.

The tentative tables for the thrust bearings that were worked out at the meeting of the Subdivision in New York City on March 18 will be transmitted abroad for consideration and acceptance by the foreign national standardizing committees before further definite action is taken on them through the Ball and Roller Bearings Division and the Society. Those in attendance at the meeting were C. N. Benson and H. E. Brunner of the S. K. F. Industries; G. R. Bott, of the Norma-Hoffmann Bearings Corporation; F. L. Brown, of the White Motor Co.; E. R. Carter, Jr., of the Fafnir Bearing Co.; D. F. Chambers, of the Bearings Co. of America; B. H. Gilpin, of the H. H. Franklin Mfg. Co.; W. P. Kennedy, of the Kennedy Engineering Corporation; H. N. Parsons, of the Strom Bearings Co. and R. S. Burnett, manager of the Standards Department of the Society of Automotive Engineers.

NEW JERSEY MOTORCOACH REGULATIONS

Members of Motorcoach Division Attend Commission Hearing in Newark

In further consideration of the proposed revision of the New Jersey Motorcoach Regulations by the New Jersey Board of Public Utility Commissioners, members of the Society's Motorcoach Division and a number of guests attended a meeting called by the Division in New York City on March 22 at which the proposed revised regulations were reviewed preparatory to attending the public hearing called by the Board in Newark, N. J., on March 23. In the main the representatives of the motorcoach builders felt that the proposed regulations are acceptable for the purpose for which they are intended and indicated a strong desire to cooperate with the New Jersey Board. No definite decision with regard to the final approval of the several items in the proposed regulations was made by the Board at the time of the public hearing and further information in this connection will be published in THE JOURNAL when it is known what final action the New Jersey Board has taken. Previous reference to this subject was made on p. 2 of the January issue and on p. 329 of the March issue of THE JOURNAL.

GROUND-RETURN WIRING SYSTEMS

Policy Committee and Electrical Equipment Division Considering Revision

The report of the Electrical Equipment Division revising the present S.A.E. Standard on Ground-Return Wiring Systems, which was referred back to the Division by the Standards Committee at its meeting in January, has been rearranged to comply with criticisms that were voiced in the discussion at that meeting.

The revised draft will be taken under consideration at a joint meeting of the Standardization Policy Committee and the Electrical Equipment Division early in April at which time it is anticipated that definite action can be taken toward approving a satisfactory recommendation to be presented to the Standards Committee in May.

Consideration will be given to incorporating the present S.A.E. Recommended Practice on Wiring Color-Code with the proposed specifications on Ground-Return Wiring Systems as a Recommended Practice under the heading of Automobile Wiring.

NEW STANDARD SPINDLE-END AND ARBOR

Milling-Machine Builders Announce New Completely Interchangeable Type

A committee of the Milling-Machine Manufacturers Group of the National Machine Tool Builders Association announces the adoption of a new standard spindle-end and arbor that will give complete interchangeability of all arbors and face milling-cutters for any size or make of milling machine from 2 to 25-hp. capacity. J. B. Armitage, chairman of the committee, states in a comprehensive report that many attempts have been made in the last few years to encourage the adoption of a standard for spindle-ends but that the machine-tool industry, like others at the time, did not realize the tremendous savings possible of attainment through standardization. The old spirit of keen commercial rivalry prevailed. The newer idea of business association and co-operative development was still in its infancy and the idea of competitors adopting standardization was less mature than it is now.

During this period, the development of the milling-machine spindle and its tool-holding elements closely paralleled the development of the milling cutter. While cutters were small and required little power to drive them, the taper hole answered all requirements. As arbor draw-in bolts were not used, the taper necessarily had to be small so that the arbors would not come out while in use. It is probable that milling-machine spindle-ends were first threaded to carry chucks, rather than face milling-cutters.

With the coming of high-speed steels and machines of greater and greater power, it was found increasingly difficult to remove face milling-cutters from threaded spindle-ends. With the threaded spindle-end, it was also found to be impractical to

run the spindle in either direction. These problems were met and solved by each manufacturer according to his own ideas, no effort being made by them to arrive at national uniformity or standardization. This resulted in each manufacturer having an individual design, often with two, three or more sizes, and to add to the obstacles in the path of standardization, many of these constructions were patented.

In the large modern shop, milling-machine equipment runs into great variety and large investment. This amount is greatly enhanced by the great variety of styles and sizes of spindle ends, which, unlike the lathe spindle, is the tool-holding element. This explains why a demand has grown among users for a standardized spindle-end for milling machines while very little has been said about lathes. This demand from the users continued to become more insistent, culminating in the announcement that the Production Division of the Standards Committee of the Society of Automotive Engineers would concern itself with efforts to standardize tool-holding and work-holding elements of machine tools.

How Standardization Was Accomplished

The milling-machine group of the National Machine Tool Builders Association met this situation in an unusual yet extremely practical manner. Instead of attempting to decide on the best of the many designs in use and adopting it as a standard, a procedure that would probably have met with slight success due to the controversial nature of the problem, a committee of engineers was appointed to pool their experiences and ideas and cooperatively produce the best possible design for use as a standard. A survey of the industry revealed the sticking taper as the one undesirable feature common to all the present types of spindle end. Practically all manufacturers had eliminated the sticking of face milling-cutters and chucks on the spindle, but nothing had been done to prevent arbors from "freezing" in the taper hole of the spindle.

The standard spindle-end and arbor as evolved by the Committee and shown in the accompanying illustration, has a taper of 3½ in. per ft., a taper that experience has shown will not freeze or stick. The taper serves only the purposes of accurately centering the arbor and providing an area of intimate contact between the arbor and spindle. The arbor is driven by tongues on the face of the spindle and a draw-in bolt of large diameter holds the arbor firmly in place. The draw-in bolt is new in design and can be tightened without subjecting it to torsional strains. Several machines were equipped with this new style spindle and arbor and thoroughly tested in different shops. These tests and research have extended over a period of more than 2 years and have included extreme tests with steep angle spiral mills set to tend to free the arbor in the spindle hole. As high as 35 hp. has been transmitted and the results of all tests have proven highly satisfactory.

Dimensions and Sizes of New Standard Arbor

To make possible greater economies to milling-machine users, a complete set of new arbors has been adopted, standardized as to length, diameter and keyway and bearing size, which can be used on any size of milling machine of from 2 to 25 hp. To facilitate ordering, a new system of numbering or nomenclature has also been adopted. The three styles of arbors standardized are Style A, Pilot Arbors; Style B, Plain Arbors and Style C, Shell End-Mill Arbors.

The standard pilot of Style A Arbors is to have diameter limits of 0.7185 maximum and 0.7180 in. minimum and be 1½ in. long. The five sizes standardized are:

Diameter, In.	Length from Shoulder to Nut, In.
⅞	10
1	12
1[a]	18
1¼	12
1¼[a]	18

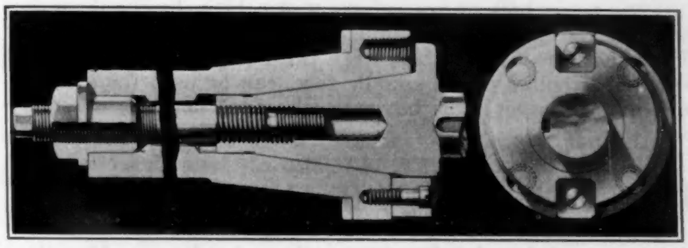
[a] These arbors also have long bearing for arbor pendant.

The 10 sizes of standardized Style B Plain Arbors are:

Diameter, In.	Length from Shoulder to Nut, In.
1	24
1¼	24
1½	18
1½	24
1½	30
1½	36
2	30
2	36
2½	30
2½	36

The threads for all arbor nuts are to be 10 threads per inch, U. S. Form, Class 2 (Free) Fit, as given in the American Standard and the Report of the National Screw Thread Commission. These arbors are to be furnished with two bearings, the bearing diameters to be selected by the customer to suit his machine.

All Style A and Style B arbors are to have the new standard keyways tentatively adopted by the cutter manufacturers and now in process of standardization by the Milling-Cutter Committee of the Sectional Committee on Small Tools and Machine-Tool Elements organized by the Society of Automotive Engineers, the American Society of Mechanical Engineers and the National Machine Tool Builders Association under American Engineering Standards Committee procedure.



Standard Milling Spindle-End and Arbor
Announced by the Milling-Machine Group of the National Machine Tool Builders Association for Capacities Ranging from 2 to 25 Hp.

Style C Arbors for shell end-mills shall conform to the standard shell end-mills now in process of standardization by the mentioned Milling-Cutter Committee.

Numbering Scheme Adopted

A standardized nomenclature or numbering adopted for the new standard arbors designates the three types as Style A, Pilot Type; Style B, Bearing or Plain Type; and Style C, Shell End-Mill Type.

The bearing sizes are designated thus:

Bearing No.	Diameter, In.	For Use with Arbors Up to and Including Diameters of, In.
3	1⅞	1¼
4	2⅛	1½
5	2¾	2
6	3⅜	2½

The arbor symbol is made up of the arbor diameter, style, the shoulder to nut length of arbor and the bearing number, thus:

1A 12 indicates a pilot arbor 1 in. in diameter and 12 in. long

1¼A 18-4 indicates a pilot arbor 1¼ in. in diameter and 18 in. long with bearings 2⅛ in. in diameter

1½B 30-5 indicates a plain arbor 1½ in. in diameter and 30 in. long with bearings 2¾ in. in diameter

For metric arbors the symbol is preceded by the letter M and the diameter is given in millimeters, thus:

M25B 30-4 indicates a plain metric arbor 24 mm. in diameter and 30 in. long with bearings 2⅛ in. in diameter

Shell end-mill or Style C Arbors, made to accommodate the proposed new standard shell end-mills, have two variables, the diameter and the distance from the face of the spindle to the back of the cutter. These two variables enter into the symbol, thus:

1½C ⅞ indicates a shell end-mill arbor 1½ in. in diameter with a projection of ⅞ in. from end of spindle to back of end-mills

While it is expected that standard shell end-mill arbors of any one diameter will be kept in stock with only one distance from end of spindle to back of cutter, the symbol allows special arbors to be ordered without confusion.

The Committee feels that while the above selected lists of arbors will cover the requirements of most manufacturers and users, it may be desirable for some manufacturers to carry other lengths in stock, such as short-stub arbors for vertical machines, while other manufacturers will not care to carry all sizes in stock. The numbering system therefore has been made flexible enough to allow for its use on sizes other than standard, thus:

1½B 3½ indicates a plain arbor 1½ in. in diameter and 3½ in. long from shoulder to nut, with no bearings

Two types of adapters have been worked out. One, fitting into the taper hole of the spindle and held in by the draw-in bolt, can be used for end-mills and collets with tang drive. The other, which registers over the outside of the spindle end and is bolted to the spindle face, can be used for arbors, end-mills or other tools having a threaded hole for draw-in bolt.

TO RECOMMEND AERONAUTIC STANDARDS

Representative Subdivisions Organized to Handle Specific Subjects

The activities of the Aeronautic Division have been advanced during the past month by the organization of five subdivisions. Four of these subdivisions will investigate and prepare recommendations for standards on the following subjects: (*a*) Engine Mountings; (*b*) Engine Controls and Fittings, (*c*) Instrument Mountings and (*d*) Tailskid Shoes. The fifth subdivision, which will be known as the Subdivision on AN Standards, will provide liaison with the AN Conferences, recommending from the adopted standards of the AN Conferences those specifications that it is believed should be an integral part of the S.A.E. Standards and, therefore, adopted by the Society.

The personnel of the Subdivisions, which includes men from the representative organizations in the industry interested in aeronautic progress, is as follows:

SUBDIVISION ON ENGINE MOUNTINGS

G. J. Mead, *Chairman*	Pratt & Whitney Aircraft Co.
F. W. Caldwell	Engineering Division of the Air Corps
Arthur Nutt	Curtiss Aeroplane & Motor Co., Inc.
A. V. Verville	Buhl-Verville Aircraft Co.

SUBDIVISION ON ENGINE CONTROLS AND FITTINGS

Arthur Nutt, *Chairman*	Curtiss Aeroplane & Motor Co., Inc.
R. S. Barnaby	Bureau of Aeronautics, Navy Department
E. T. Jones	Wright Aeronautical Corporation
K. H. White	Chance Vought Aircraft Corporation

SUBDIVISION ON INSTRUMENT MOUNTINGS

Archibald Black, *Chairman*	Garden City
C. H. Colvin	Pioneer Instrument Co.
W. W. Frymoyer	Foxboro Co.
M. F. Schoeffel	Bureau of Aeronautics, Navy Department

SUBDIVISION ON TAILSKID SHOES

T. P. Wright, *Chairman*	Curtiss Aeroplane & Motor Co., Inc.
J. A. Roche	Engineering Division of the Air Corps
Mac Short	Massachusetts Institute of Technology

SUBDIVISION ON AN STANDARDS

E. P. Warner, *Chairman*	Assistant Secretary of the Navy for Aeronautics
R. S. Barnaby	Bureau of Aeronautics, Navy Department
V. E. Clark	Consolidated Aircraft Corporation
Leslie MacDill	Engineering Division of the Air Service
Edward Wallace	Glenn L. Martin Co.

ACTIVITIES OF THE SECTIONS

CELEBRITIES AT WASHINGTON DINNER

MacCracken and Davison, Major Walsh and L. D. Gardner Give Addresses

Army and Navy officers and many other persons who are greatly interested in aviation were sprinkled liberally among the nearly 100 persons who attended the Air Transport Dinner held by the Washington Section in the main ballroom of the City Club in the City of Washington on the evening of March 18. The guests of honor who spoke were the Hon. William P. MacCracken, Jr., assistant secretary of commerce for aeronautics; the Hon. F. Trubee Davison, assistant secretary of war for aeronautics; Raycroft Walsh, of the McGraw-Hill Publishing Co., and Lester D. Gardner, publisher of *Aviation*.

The speakers' table was decorated with five model airplanes, and a large flag bearing the emblem of the Society hung along one side of the room. During the dinner the Columbian Male Quartet furnished vocal entertainment. John O. Eisinger, of the Bureau of Standards, officiated as toastmaster owing to the unavoidable absence of C. F. Clarkson, who was on the program to deliver an address of welcome.

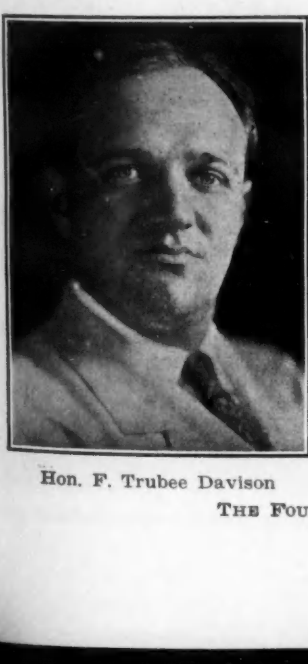
Following brief remarks on aeronautics by the Assistant Secretary of Commerce, Mr. Gardner gave an interesting address on air transport in Europe and showed many lantern slides of views taken on his 21,000 miles of travel on the European airways and several new slides of the Hanging Gardens of Babylon and other places and objects of interest. He also showed some new types of hospital or ambulance airplane that are now used for passenger service but can be converted readily into air ambulances. Some of the subject matter was contained in Mr. Gardner's address at the Annual Meeting of the Society.

Some of the difficulties likely to be encountered in any undertaking such as the present Good-Will Flight of the Air Service through Central America and around South America, were explained by the Assistant Secretary of War, who stated that the primary object of this air journey is, as the term implies, to establish more cordial relations between the United States and the republics to the south.

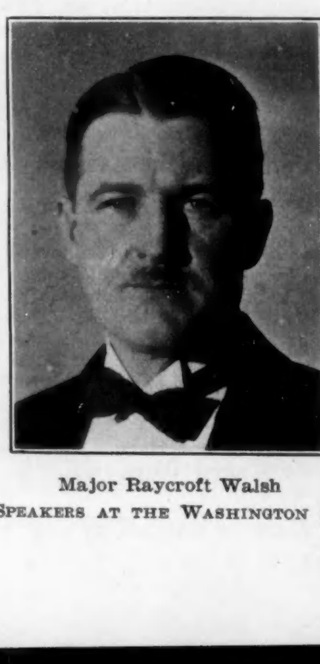
Walsh Tells of Courtesy Flight

Mr. Davison then introduced Mr. Walsh, who was flight commander of the Army Air Service Courtesy Flight through Central America last year. Experiences on that trip were portrayed vividly by Mr. Walsh both verbally and optically with lantern slides and motion pictures. Characteristic views of the territory flown over, of the volcanoes, jungle, bad lands, serpentine railroads, and capital cities are given on p. 433. The narrative took the audience with the fliers from the France Field air-station on the Atlantic side of Panama to the Pacific side along the canal to San Jose in Costa Rica, to Managua in Nicaragua, to Salvador, Guatemala City and almost to the southern border of Mexico, where the expedition turned back, possibly because our relations with the last-named country were already so cordial. Honduras was also avoided because one of the frequent sudden revolutions had broken out since the letter from our Government to the President of Honduras was written, and, as the government of Honduras had changed hands, it was thought that presentation of the letter to the new President would obligate the United States to recognize the new government.

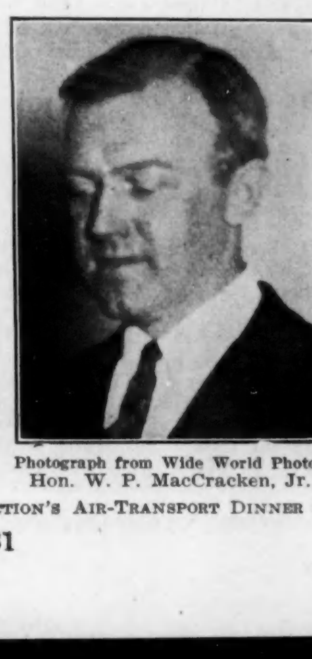
Relations with the Panamaians already were most cordial,



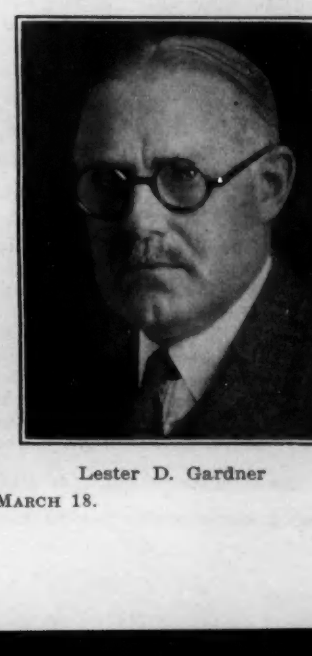
Hon. F. Trubee Davison



Major Raycroft Walsh



Photograph from Wide World Photos
Hon. W. P. MacCracken, Jr.



Lester D. Gardner

THE FOUR SPEAKERS AT THE WASHINGTON SECTION'S AIR-TRANSPORT DINNER OF MARCH 18.

as the United States Air Service had carried serum and small pox vaccine on numerous occasions to generals in the Panama-Costa Rica war and into the interior of Panama, and had also helped injured people in the interior, said Mr. Walsh. Favors had been shown the supervisor of telegraphs by taking him on inspection trips by airplane in about 2 hr. that would have required 3 or 4 days on horseback. As a result, excellent telegraph service was rendered the Courtesy Flight men in Panama, and when the bombing airplane developed engine trouble and was forced to make a landing, a telegraph messenger appeared quickly and asked if anything was wanted.

San Jose has a wonderful flying field, although high trees at either end make it rather hazardous unless the wind is blowing directly up or down the field, according to the speaker. Mexican influence, which next to that of the United States, is strongest throughout Central America, is reflected by wireless towers at the flying field, which were presented by the Mexican government. The President of Costa Rica was invited to make a trial flight in one of the airplanes and while in the air talked with the padres in the College of San Jose by radio and created considerable of a sensation.

Unbroken jungle was traversed for 70 miles over the watershed leading into Lake Nicaragua, and here the easterly trade wind forced the airplanes higher and higher, although the engines were well throttled down, and the air was so "rough" that all members of the expedition became air-sick except the pilot. While flying over one of the active volcanoes to get a good photograph, the fumes from the crater also caused some trouble, from which the expedition recovered a little later. Crater lakes to the northward from Managua are so deeply hidden that the fliers had to be almost over them before they could locate them.

All through Central America the soldiers and officials wear firearms, said Mr. Walsh. One of the Courtesy fliers, who had been considerably incommoded on a 7-mile flight with a Salvadorean aide by something hard pressing against his ribs, noticed when the aide got out that he carried a big automatic pistol under his blouse, with the muzzle down. It was this that had been tickling the pilot in the side all the time.

Numerous other graphic incidents of the trip were related to show the nature of the countries, the character of the peoples and the construction of the cities and buildings.

FASTER DRIVING-RANGES INEVITABLE

Milwaukee Section Told That Motor-Vehicles Need Two Quiet Driving-Ranges

The purpose of the speaker at the Milwaukee Section meeting that was held on March 2 at the Blatz Hotel, Milwaukee, was to show some of the designs and devices worked out in an effort to promote the idea of incorporating in motor-vehicle construction means for obtaining quiet driving-ranges. The paper was presented by Thomas L. Fawick, of the Thomas L. Fawick Co., Racine, Wis. The ranges referred to are a quiet driving-range for both light and heavy traffic and another quiet range suitable for driving over paved roads where low engine-speed and fast car-speed are of vital importance to satisfactory performance. The speaker's argument was that engine-speeds must be reduced to secure maximum economy, long life and comfort. He asserted that smoothness and quietness of operation at high speeds are the most outstanding incentives for using a quiet fourth-speed. According to the speaker, cars equipped with a fourth speed of the type he described are driven for from 80 to 95 per cent of their total mileage while operating in the higher ratio. This of course requires that means must be provided for shifting easily from fourth to third speed or vice versa. He then went on to explain the devices under development.

With regard to the four-speed transmission-and-axle combination, Mr. Fawick described a small transmission unit having a bell housing in which there are no countershafts and no idling gears when in direct drive. He said that this unit is a distinct two-speed-forward-and-reverse transmission incorporating a clutch shaft-gear or sun-gear, three planet gears and a longitudinally movable gear that can be set in low, in reverse, in direct or in neutral position. The transmission is arranged with two gearshift shafts, the second shaft to be arranged for shifting the two-speed rear-axle ratio-changing device. This provides, he said, four speeds forward and two in reverse. When in either of the two higher ratios there are no idling parts, no internal gearing or spur-gearing in the transmission; it is merely a direct drive through the transmission and therefore it is not likely to cause any noise from the gearbox when in either of the direct ratios.

The ratio-changing gear-device at the axle operates as a gear only when on third speed. Fourth speed is direct drive and the gears are locked together the same as in any differential gear; therefore, with from 80 to 95 per cent of the driving done on the fourth ratio there is an exceptionally small amount of wear developed in the axle-speed change-device or differential.

Mr. Fawick also discussed six-speed transmission internal-gear over-drive. He said that the six-speed transmission internal-gear can be left in mesh with the clutch socket of the internal gear or with the internal gear. When left in direct engagement, the transmission is operated as a standard conventional three-speed unit. If the auxiliary lever is shifted to place the pinion in mesh with the internal gear, then each of the first, the second, the third and the reverse ratio is stepped up to be 1.29 to 1.00. He stated that several thousand of these units are now in operation.

Proper Lubrication Essential

In the course of the discussion following the paper and in reply to a question, Mr. Fawick said that proper lubrication of these devices is very important. Without proper oiling, the devices will be noisy and wear out sooner. He mentioned

Views Taken on the Airplane Courtesy Expedition through Central America by the Army Air Service

The Illustration at the Top (1) Shows Fuego, One of the Three Volcanoes Guarding Gautemala City, with Acatenango and Agua in the Background; All Three are Over 12,000 Ft. High. The Top View at the Left (2) Shows One of the Forest Fires That Were Seen by the Expedition. Some Idea of the Character of the Territory Flown Over by the Expedition Can Be Gathered from the Top View at the Right and the Central View at the Left, These Being Respectively a View of the Jungle near the Border between the Republics of Panama and Costa Rica (3) and a View of the Bad Lands near Penonome, Republic of Panama (4). At the Central Right Is a View (5) Showing a Series of Curves on the Railroad Connecting San Jose with Guatemala City. The View at the Lower Left (6) Is of the Santiago Volcano in Nicaragua, One of the Volcanoes That Are So Numerous in Central America, Showing the Active Crater in the Background and a Dead Crater in the Foreground. Managua, the Capital of Nicaragua, Which Is Figuring So Prominently in the Daily Press, Is Shown in the Lower Right Corner (7) the Campo del Marte, Where "the Marines Have Landed and Have the Situation Well in Hand" Can Be Seen in the Central Foreground

For Description of These Photographs See P. 432

an instance of a motorcoach that had run about 40,000 miles and that then was run carelessly without proper oiling. After the vehicle had run a total of 50,000 miles, the gears failed because of the heat generated by friction when they were not sufficiently lubricated.

Questioned regarding the prevention of warpage when producing the gears and the precautions taken to make the gears concentric, Mr. Fawick said that the forgings are normalized after coming from the hammers, having been forged to have the minimum amount of excess stock. They are then machined completely, grinding stock being left on the bearing-surfaces. The gear is set in the gear-shaping machine so that the outside periphery runs true and, before the gear is hardened, the pitch-line is made concentric and true with respect to the outside periphery. After hardening, the gear is trued with reference to its outside diameter in a grinding-machine.

ENGINEERING STAGE OF THE INDUSTRY

Day of Domination by the Engineer Has Come, Moskovics Tells Chicago Section

Prediction that from this time on the engineer will be a more important factor in the automotive industry than ever before was made by F. E. Moskovics at the monthly meeting of the Chicago Section on March 8. He made the statements that the day of reasonable domination by the engineer in this industry is here; the engineer who can give the public what it wants is worth his weight in gold to any manufacturer and any sales organization and he has the greatest future that any technician in any industry in the history of the world has ever had. Mr. Moskovics spoke extemporaneously on the topic, The Engineering Stage of the Automobile Industry Has Arrived.

F. E. Moskovics

Preceding delivery of the address, O. W. Young, who presided as chairman, took a vote of the meeting on the question of holding a meeting in May and the character of the meeting if held. This showed a preference for holding a meeting and of devoting it to a technical session instead of to golf. The proposal made by the Society headquarters to include the counties of Cook, Du Page, Lake, and Will in the membership territory of the Chicago Section was also duly ratified.

As a matter of new business, L. W. Oldfield referred to misleading advertisements of gasoline economizers in daily newspapers and suggested that some action be taken with regard to them. If a gain in mileage is made by a car after such a device has been installed, he said, the improvement in mileage is not due to the device but because the carbureter was not properly adjusted before. R. E. Wilson said that the engineers owe some measure of protection to the public and must also protect themselves against unfounded claims for efficiency of devices to be added to the car and proposed the adoption of a resolution to be forwarded to the papers deploring the acceptance by them of misleading advertisements and expressing the hope that the papers would investigate the claims made before printing the advertisements in future. This suggestion was put in the form of a motion, which was seconded, and the chair appointed Mr. Oldfield to draft a resolution and submit it to F. G. Whittington, secretary of the Section. Lloyd Maxwell was then called upon to introduce Mr. Moskovics as the speaker of the evening.

Public Accepts Any Article of Merit

We are now in a period of refining developments and have a great advantage, said Mr. Moskovics. The public is prepared to accept any meritorious article and the motor-car more than any other one thing has made the American nation a mechanical nation. The nomenclature of mechanics is a common language in which the engineer can talk to the buying public. If an article has a purpose, definite merit and value it has a right to existence, and, if it is mechanical and sound, one need not be afraid to go ahead with it. A greater technical change in motor-cars will occur in the next 4 years than in the last decade, Mr. Moskovics predicted. This puts upon engineers a responsibility that cannot be overlooked. It means that an obligation is assumed that must be fulfilled because a few new devices that are bad and that do not function as they should can spoil the situation.

The fact of greatest importance is that the public understands the value of good and poor mechanical articles and competition is forcing the manufacturer's hand. Any man with a radically different automotive part or accessory can secure an open reception today in any laboratory or engineering department or in the general manager's department, because the general manager is looking for something with which to meet competition.

The public as a whole, said Mr. Moskovics, is demanding better automobiles and wants every improvement that can be put into the modern vehicle, and it is the engineer's part to make the improvements. If every mile of road in the United States were hard surfaced, 1000 lb. could be taken out of every new automobile built, but today automobiles are built to meet the conditions on unimproved highways. Automobile engineers have a tendency to stultify themselves because of too much pressure from the advertising and other departments, he continued. One department wants a low price and another wants high speed. The cheapest way to secure the latter is to buy speedomoters that register too high, but even this is sometimes abortive in effect, according to the speaker. Mr. Moskovics narrated the incident of an engineer who wanted to adopt a certain device, but who, when told that the total cost of the device was about $4.25, said that he could not use it because the management would not pay the price. Was he fair to the public and to his own stockholders? Mr. Moskovics inquired. The engineer admitted that his cars would give trouble within 3000 miles if they did not have the device. If the service department of the company makes even a semblance of taking care of customers, the cost to it because of the absence of the device will be twice the price of the article that should be installed. This kind of engineering will not make the automobile industry progress and will not mean success for the engineer.

Industry Wide Open for the Engineer

The industry is wider open for the engineer than ever before, continued Mr. Moskovics. At present seven different types of eight-cylinder cars and at least seven different forms of fourth-speed gears are in the market. Not many engineers, however, understand exactly what the fourth-speed engagement will mean to them. To illustrate this he referred to a foreign engineer who put a fourth-speed gear in a little car that needs mechanical flexibility and uses a three-speed gear with a big flexible engine. Other engineers are doing similar things without due consideration of all the factors involved in what they are trying to accomplish, such as the relation of flexibility of the engine to the weight carried.

Referring to the engineering difference in bodies, the speaker said that the flexible fabric body is so radically different from the rigid type of steel body that it brings in an entirely new factor. Mr. Bugatti told him, said Mr. Moskovics, that if he was sure that the public would accept them he would put nothing but this type of body on his cars because, by saving 500 lb. in body weight, another 500 lb. could be taken out of the chassis and thus make the car approximately 1000 lb. lighter and a much better job. To indicate what this decreased body weight alone means, the speaker told of a test made with two identical cars of his own make except that one developed 28 hp. less than the other and

was fitted with a flexible body that made it 538 lb. lighter than the other car. This car repeatedly beat the other one by 1 sec. up a hill at full-open throttle. This means better acceleration and also good performance on the fuel at top speed.

The engineering trend of the industry never was broader than it is today and the public never was more receptive to new developments. Some new constructions he saw in Europe were startling, said Mr. Moskovics, and they are coming on the market soon. He spoke of four different forms of rotary valve that he saw on a recent trip to the Pacific Coast and told of an engineer making the statement on the day of the meeting that he did not think that a turbine gas-engine ever would be an assured success. "I would not care to take the liberty of making such a statement," commented Mr. Moskovics.

The real engineer of the future must be a creative artist, an executive and an engineer. He must know the elements of production and above all must know, as the creative artist does, what the public wants. He must be able to interpret the desires of the public in definite terms of the motor-car. The engineer who can do this best will be in greatest demand and win the greatest success. The public is motor-wise and will listen to straight talk. The speaker predicted that the era of gross exaggeration in advertisements will not persist indefinitely and referred to the ridicule heaped upon extravagant claims of speed for various makes of car by speakers at the Annual Banquet of the National Automobile Chamber of Commerce last January as significant of a tendency toward a more healthy condition. Several companies that have made such wild claims in their advertising are now making desperate efforts to catch up with the advertising. It is good, however, to have the advertising man a little ahead of the engineer, as that puts the responsibility upon the engineer to catch up with him.

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THE CONSUMER DECIDES

L. W. Oldfield asked Mr. Moskovics, at the conclusion of his talk, for his opinion as to the difficulties an engineer faces in approaching a real production organization that is tooled-up and in heavy production on a more or less conventional design with something radically different that would throw out of the production line a large part of the equipment. He said that Mr. Moskovics in his own organization had demonstrated his belief in the feasibility of introducing new ideas by showing courage enough to do one or two things very differently in the present car.

In answer, Mr. Moskovics said that this is decided by the ultimate consumer and that if the engineer went to a manufacturer of a conventional design with a radical device, it would take the manufacturer at least 3 years to determine its utility and he would spend many thousands and perhaps hundreds of thousands of dollars in doing so. The car built by his own organization was 6 years in its conception, more than $350,000 was spent before the first car was produced and it was necessary to make use of other men's money. The idea must be sold to the manufacturer long before the heavy tooling-up cost arises. No manufacturer will spend from $4,000,000 to $15,000,000 in preparing to manufacture something until he is sure that it is good, but all are waiting today for some device or idea that they can be certain is worthwhile. The largest builder of automobiles in the world, he said, has been experimenting for 10 years with a radial-type air-cooled engine on which he has spent hundreds of thousands of dollars. To put cars with this engine in production would cost $20,000,000, but when competition becomes so severe that his factories are threatened with idleness, the cost will not be a drop in the bucket. Money is waiting today more than ever to take up new ideas, because the banker is in the automobile business and when his own money is at stake he is a good gambler. A banker is like an engineer; he is willing to experiment with your business at your expense, asserted the speaker. The present situation in business is rapidly driving men with capital into the adoption of new ideas.

FOREIGN-TYPE LIGHT-CAR'S CHANCES HERE

Asked his opinion as to the salability in this Country of really small cars not at present in the market, Mr. Moskovics said that his investigation of the small-car field in Europe showed that the Riley, Austin and the little Peugeot were the only cars of 61-cu. in. piston displacement that really amount to anything and Citroen has given up production of the 5-hp. car. In an attempt to drive one of these small cars up St. Germain Hill in Paris, which any American car can take in high gear at 5 or 10 m.p.h., he rushed the car with wide-open throttle at a little more than 40 m.p.h. but could not drive it more than half way up the hill without shifting gears. The car had a 36-in. tread, which would make it easy to turn over and which would not be suitable for American conditions of the paved highways. Unless the tread is less than 40 in., weight cannot be saved. He estimated that the maximum sale of such cars in America might be 100,000. The foreign car of 2⅓ liters (122 cu. in.) piston displacement develops 60 hp. and would not be called a small car. The 6-hp. Renault has a piston displacement of 1½ liters (79 cu. in.) and is a good sized automobile. The 7-hp. Fiat has a 52-in. tread and is a very large car. Mr. Moskovics said that he does not see any probability of extensive use of such cars until road conditions are definitely more equalized in this Country and also said that Europe is now going to larger cars.

Secretary Whittington reverted to the subject of fast-reading speedometers, and Mr. Moskovics said that, while at present the car builder who puts on an accurate speedometer is at a disadvantage, the desire for the thrill that comes with the use of a fast-reading speedometer is only a momentary hysteria and eventually the public will test the car-speed and the speedometer and find out which car actually develops the highest speed. Car owners do this in Indianapolis on the Speedway with a stop-watch. In this connection Walter Martin remarked that on a State highway running the full length of the State of Illinois car drivers can test the accuracy of their speedometers by mileage posts plainly marked as speedometer-test posts for a distance of 10 miles along an absolutely straight road.

Much of the rest of the discussion was taken up by Mr. Moskovics with comments upon the Bugatti racing cars and their construction and with a description of the new Bugatti big car, that, he said, has a wheelbase of 176 in., a cylinder-block 58 in. long and of 850 or 860-cu. in. capacity and the maximum engine-speed of 2000 r.p.m. Although remarkably light for its size, the car weighs more than 3700 lb. It is geared 2 to 1 on top gear, has 38-in. wheels with double tires, and every piece of the car is made by hand. It would have to sell in America, with a closed body, for about $38,000. Another new Bugatti car has 143-cu. in. cylinder capacity and the builder says he will guarantee it to do 120 m.p.h. Mr. Moskovics said that he was trying to induce Mr. Bugatti to come to the United States this year and to attend the Indianapolis races, in which case he will attend the Semi-Annual Meeting of the Society.

INDIANAPOLIS OIL-ENGINE-CAR RACE-PLANS

Asked by Mr. Oldfield for his views with regard to changing the rules governing races so that they will develop something other than high-speed engines, Mr. Moskovics

told of obstacles built in the finishing straightaway in the last Grand Prix Race in Europe, which were so placed as to necessitate the cars' slowing down to 15 m.p.h. to make a sharp turn and require quick gearshifts. One race like that in Indianapolis, he said, would show engineers in this Country how to build cars with suitable gearshifts.

The speaker then told of plans for a 24-hr. race at Indianapolis for oil-engine cars. The rules will provide that the car must be started with the driver in his seat and may start on any fuel, but after it has been started all electrical ignition and other fuel must be disconnected so that the car will run on low-grade oil only. Neither electrical ignition nor hot tubes can be used, which means that the engine must be of the Diesel-cycle type. The cars must stop every 2 hr. and start again under their own power, and neither size nor design are limited. A prize of $25,000 has been offered by Carl Fisher and several associates for the winner of the race.

Asked by George W. Cravens if he saw any oil engines for automotive purposes in Europe, Mr. Moskovics said that, although he was in practically every factory in France and Germany, he did not see a single oil-burning engine in any prominent factory nor to his knowledge was any one working on one in any such factory in the two countries, although one truck company was building one of nearly 500-cu. in. cylinder capacity.

AUTOMOTIVE TRENDS AND BRAKES

President Hunt and J. R. Cautley Address Two Meetings of the Dayton Section

Two meetings were held during March by the Dayton Section, the first on March 1 being the postponed February meeting. This meeting, a joint meeting of the Dayton Section and the Engineers Club, was addressed by President J. H. Hunt on Trends in the Automotive Industry. At the second meeting, held on March 22, John R. Cautley discussed the subject, Brakes a Vital Factor for Automobile and Airplanes. As is customary, a dinner preceded each meeting.

PRESENT STATUS OF THE MOTOR-TRUCK

Eminent Authorities Address Metropolitan Section's First Annual Truck Meeting

What the motor-truck has been, is and will be, with emphasis on the *is* and numerous question marks following the *will be,* constituted a 10 or 15-ton subject that was well threshed out at the St. Patrick's Day meeting of the Metropolitan Section which was held on March 17 at the Hotel Woodstock, New York City. The Section's *Booster*, printed in orange and green, was what started the fight. But the favors at the feature dinner were mainly green and so was the ice cream and, by the time the 10-min. talks were about to be begun, everything was inclined to be lovely. Trouble developed then, however, for it was discovered that T. C. Smith, engineer in charge of automotive labor-saving apparatus for the American Telephone & Telegraph Co., New York City, was anything but a green chairman and that all the speakers were anything but greenhorns. The impending fracas was compromised when it developed that all their stuff was in the heavyweight class, and that each speaker was to be silenced by a "persuader" if he tried to talk too long.

Orderly Development with Few Major Changes

In opening the symposium, B. B. Bachman, engineer of the Autocar Co., Ardmore, Pa., said that most truck builders have concentrated on orderly development of the vehicle with as few major changes as is consistent with changing conditions. The development of the vehicle built by his company has back of it the idea of maneuverability in places where space is at a premium. He referred to intercity hauling and to hauling over highways outside distinctly urban areas. Traffic congestion, he said, particularly in cities, and increasingly so in suburban areas on main-traveled highways, has developed the need for and a tendency toward replacement of large units by multiples of smaller units. For this and other reasons, his company has added to its line of vehicles a lighter model of the speed-type class, thus providing a more-flexible unit.

Among the newer features, Mr. Bachman mentioned a lighter chassis, improved body and the adoption of four-wheel brakes. Of the last feature he remarked that experience has proved to his company's satisfaction that servo-mechanism for applying brakes on a heavy vehicle is not necessary. Other successful features mentioned by Mr. Bachman included satisfactory pedal-pressures, exceptional length of life of the braking mechanism, the use of air-cleaners and the installation of aluminum pistons. These last were said by the speaker to be entirely satisfactory mechanically and to offer many advantages not hitherto foreseen.

Four-Wheel Drive

Speaking on the subject of the new demand for greater range in truck performance as met by the four-wheel drive, E. R. Greer, consulting engineer for the Four Wheel Drive Auto Co., Clintonville, Wis., stated that proof of a present demand for greater truck performance is given conclusively by the present trend in truck design, by the fact that truck prices generally are increasing in spite of improved methods of construction and by the increase in the number of large trucks that are being sold. With reference to the four-wheel-drive truck, this has always stood for greater range in performance according to Mr. Greer. He said that 1½, 3 and 5-ton sizes of truck are built but that the 3-ton size is the specialty. To increase the range, it is necessary to (*a*) use high-grade material and careful workmanship, (*b*) increase the power, (*c*) increase the number of selective speeds in transmissions, (*d*) secure increased traction and (*e*) improve the control, especially in regard to brakes. He said that the great test of a truck's utility lies in its ability to transport its load from the point where the load originates, over a good road, and to deliver the load to a point at which the load will be used, the delivery point usually not being on a good road.

Referring to the new four-wheel-drive truck having five-speed transmission and single-lever control, Mr. Greer said that it has a speed-change range of 9.95 to 1.00. He said also that where 50 to 1 formerly was considered a low gear-ratio, a ratio of 120 to 1 is not uncommon at present. Dividing the tractive effort among four wheels instead of two also divides the strains, provides greater traction and eliminates the waste of power in pushing so-called "progress-resisting" front-wheels. With four driving-wheels, the load on the truck can be shifted to distribute it more equally between all the wheels and spreading the load results in less damage to the roads, with consequent lessened strain on truck parts. But the important factor in Mr. Greer's opinion is the greater traction available. He mentioned also the greater need of safe brakes on trucks than on passenger automobiles and stated that four-wheel-drive truck brakes are equipped to have equalized brake-action on all four wheels.

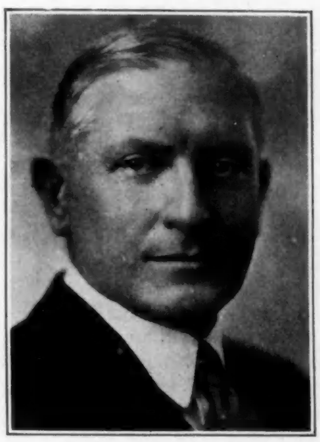
Summary of Truck Design

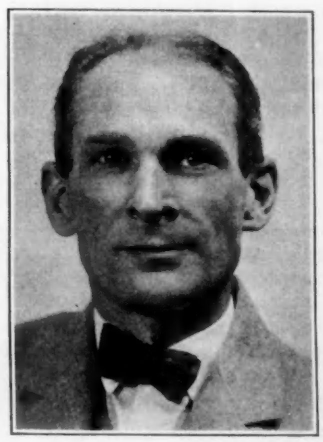
Summarizing modern truck-design, S. W. Mills, chief engineer of the Pierce-Arrow Motor Car Co., Buffalo, stated that the most conspicuous features are larger factors of safety, engine refinements, more powerful brakes applied with minimum effort, easier steering, faster road-speed and pneumatic tires of both the single and the dual type. He said that the larger factors of safety have been necessitated by overloading of trucks, the result having been an increasing use of the best alloy-steels and other features providing added strength. Frame side-members are of heat-treated nickel-steel, relying on carefully located rivets and bolts in the vertical section to secure brackets and cross-members. Very careful consideration is needed as to the design and the material used in rear axles. Shafts are invariably of the best heat-treated

alloy-steel. Particular attention is being given to adequate-bearing proportions, rigidity of mounting and lubrication. Gearing must be of great strength and very rigidly mounted. The most popular type of heavy axle is now the full-floating type, using a pressed-steel housing; simplicity and ample proportions to carry 50-per cent overload are demanded. Front axles are receiving more careful attention as to the material and section used for knuckles. Roller-bearings for the knuckle-spindles find favor.

Spring mounting to reduce the danger of loosening to the minimum was mentioned by Mr. Mills as necessary, and he said also that nothing but heat-treated alloy-steel should be used for spring clips. Larger spring-bolts, with consequent increased bearing-area, and proper lubrication are needed features. He then went on to comment on trends in transmission design, shafts, material for gears, clutches and engine design. Regarding the last item he said that the four-cylinder-block casting predominates, although six cylinders, especially for the lighter trucks, are increasingly popular. General practice includes force-feed lubrication of all bearings, heavy crankshafts carefully balanced and substantial wearing-surfaces. He then made comments on wheels, tires, radiators, the electrical equipment and brakes. As to the last feature he said that brakes applied by power supplied to them are also increasing in favor and have proved their reliability, especially in the case of tractors and


E. A. Johnston


W. G. Hawley


Stanley W. Mills


B. B. Bachman

FOUR OF THE SPEAKERS AT THE ST. PATRICK'S DAY MEETING OF THE METROPOLITAN SECTION

trailers where the problem of mechanically applied brakes is a very difficult one.

Heavy-Duty High-Speed Freight-Truck

The recent development of a heavy-duty high-speed freight-hauling motor-truck by the American LaFrance Fire Engine Co., Inc., Elmira, N. Y., was described by W. G. Hawley, chief engineer for that company. The purpose of the design was to combine the best features of heavy-duty truck-design with the smoothness of operation, ease of steering and braking facilities of a passenger-car and also to provide for driver comfort, convenience of control, weather protection and good appearance. Speeds of from 25 to 35 m.p.h. were thought to be safe and practicable for such a vehicle, considered in respect to average road and traffic conditions. Pneumatic tires were necessitated by these road-speeds and 8-in. equipment, using dual tires at the rear and single tires at the front, was said to permit a pay load of 5 tons without overloading. Mr. Hawley then went on to enumerate some of the more characteristic features of the design of this vehicle.

Engineering Problems

The remarks of E. A. Johnston, director of engineering for the International Harvester Co., Chicago, touched briefly upon the more general engineering problems connected with motor-truck engineering which he said include production, sales, operation, and service problems. The truck manufacturer is interested mainly in production and sale; the purchaser in the low cost of haulage. Although a motor-truck may be ideal from an engineering viewpoint, it may at the same time be unsuccessful commercially, for, after the motor-truck design is completed, the production problems begin to appear and must be solved.

The speaker said that the success of motor-truck engineering depends upon efficient production, sale at a profit and satisfaction to the purchaser. Production cost, which largely determines the price, as well as salability, are important engineering factors. The engineer should be concerned with a consistent practical standardized method of rating. Normal, nominal, maximum and other methods of rating often have not proved entirely satisfactory and in many cases are responsible for unsatisfactory operation or failure of a motor-truck. Lack of a standardized method of rating has indirectly been largely responsible for the enactment of many inconsistent and undesirable laws intended to protect the highways and also for licensing purposes. Some of these laws that limit the total weight of the loaded truck result in a strong tendency toward lighter chassis and pay loads much heavier than the truck is designed to carry. Mr. Johnston commented unfavorably upon the great variety of motor-truck models and capacities now existing.

It was suggested by the speaker that a set of standards be developed which would be entirely satisfactory to manufacturers, acceptable for licensing purposes, have a tendency to discourage undesirable legislation and result in great benefit to the industry. He mentioned three desirable capacities for the light motor-truck class; namely, 1000 to 1500 lb., 2000 to 3000 lb., and 4000 to 6000 lb. In the heavy-duty class he named four desirable capacities; namely, 4000 to 6000 lb., 6000 to 9000 lb., 10,000 to 15,000 lb., and 15,000 to 25,000 lb. He believes that these ratings would answer every purpose and tend to minimize engineering, manufacturing and sales complications, the indirect result being a great saving to the industry. He includes salability with other engineering problems, separating it into five component parts; these are appearance, quietness of operation, freedom from excessive vibration, comfort of the driver, and ease of operation.

Extending profitable operation of trucks was said by the speaker to be dependent largely upon the development of trucks and trailers that will handle sufficient tonnage at a speed which will reduce the cost per ton-mile to the minimum without excessive destruction to the roads. The situation can be met by reducing the weight of the chassis, especially the unsprung weight; by increasing road-speeds; and by using pneumatic tires, trailers, semi-trailers, an additional pair of wheels, or six-wheel vehicles. In conclusion, after mentioning service as one of the most important factors responsible for the success of the motor-truck industry, the speaker said that the scope of motor-truck engineering must

be broadened to include every factor and problem involved from the first line on the drawing-board to the satisfied purchaser.

Use of Light Trucks for Haulage

Referring to the 1¼ and 2-ton trucks built by the Reo Motor Car Co., Lansing, Mich., C. F. Magoffin, the company's chief engineer, said in part that since 1924, when all the vehicles were equipped with four-cylinder engines, the average of engine installation for 1926 was 20 per cent four-cylinder and 80 per cent six-cylinder engines. The reason stated was that the length of life of the six-cylinder engine has been found to be longer than that of the four-cylinder engine, the parts lighter and the vibration less. Economy for the six-cylinder engine was said to average about the same as for the four-cylinder type, and the operation of the former was said to be superior. The present trend is not to use four-cylinder engines. Numerous lantern-slides of various types of Reo vehicle were exhibited by Mr. Magoffin, who called attention to their special features of interest bearing upon design and specific utility.

Six-Wheel Trucks

Speaking for A. F. Masury, of the International Motor Co., New York City, some of the developments of this company were summarized by Charles Froesch, its engineer. He said in part that the company has been seeking continuously to apply the use of rubber under compression wherever it is necessary to absorb shocks, dampen vibration, provide a resilient connection and reduce wear without sacrificing structural strength. He divided the majority of truck requirements into (*a*) heavy hauling and dump work and (*b*) the rapid transportation of perishable goods.

Describing the six-wheel vehicle, a new model recently perfected by the company, Mr. Froesch said that the two rear axles are spaced 46 in. apart. The drive is through the forward rear-axle only, using the conventional chain and radius-rod. Two inverted semi-elliptic springs are used, one being located above and the other under the axles. A booster brake is interposed between the pedal and the jackshaft for service work, and the emergency brake control is by two separate hand-levers; one of these acts on one rear-axle and the other acts on the second rear-axle. When coasting, it is then possible to use either set of brakes intermittently, thus preventing overheating. One model has a 180-in. wheelbase, measured between the front axle and the forward rear-axle; the other model has a 128-in. wheelbase and is being used for dump work. The chassis weight is about 13,000 lb. Mr. Froesch described also a large-size fire-department unit for pumping, equipped with a rotary pump. This has a six-cylinder engine and a three-speed pump-transmission, separate from the drive transmission; the weight is 14,000 lb.

Improvements in Engines

Remarks by H. D. Church, director of engineering for the White Motor Co., Cleveland, reviewed the recent improvements in the trucks built by his company. Due to illness he was unable to be present and the remarks were read by G. W. Smith. Mr. Church said that the most important improvements lie in the engines for the heavy-duty and the medium-duty trucks. Special attention has been given to engine lubrication. Oil is delivered under pressure to all main bearing-surfaces, is conducted through drilled passages or steel tubes to eliminate pockets that accumulate dirt and, in addition, an automatic blow-off valve is provided which is metered progressively for variations in viscosity, having a fixed adjustable orifice located at the end of the main delivery-passage. This adjustable valve varies the oil pressure directly with the speed of the engine, and the surplus oil is discharged through this valve into the timing-gear case and is led from this point to the bearings of the magneto and water-pump drive-shafts, returning thence to the oil reservoir. Mr. Church, after going into further detail regarding the lubrication system, said that machined combustion-chambers, and the balancing to close limits of the pistons, connecting-rods, crankshaft, flywheel, clutch and drive-shaft assemblies, are other important features that have resulted in a general improvement of the company's four-cylinder truck-engines. He also mentioned features of the company's heavy-duty chassis and of its new high-speed medium-duty truck.

Summary

A. W. S. Herrington, consulting engineer, City of Washington, in summarizing the points made by the previous speakers, said in part that he agrees with Mr. Bachman as to the trend from the large to the small motor-truck. He mentioned the need of four-wheel brakes, better acceleration and better performance for this higher-speed vehicle to correspond with the general speeding-up of traffic that is now in progress. He remarked further that he believes the motor-truck interests do not realize the extent to which the four-wheel-drive principle will be utilized in the future. With the present engines available, his opinion is that a gear-ratio of 120 to 1, mentioned by Mr. Greer, probably will permit turning all the four wheels under the worst conditions, and he believes that gear-ratios lower than that will be used. He is in agreement with the comments on frame design made by Mr. Mills.

In reference to Mr. Hawley's remarks, Mr. Herrington favors the six-cylinder rather than the four-cylinder engine in connection with the speeding-up of heavy-duty trucks. Regarding the indirect problems of engineering outlined by Mr. Johnston, the speaker said that following the design and production of the vehicle, to say that 50 per cent of the cost of operation of any vehicle in commercial service is dependent upon the driver and the driver's control is a conservative estimate. He stated also the following statistics regarding six-cylinder engines, in connection with Mr. Magoffin's remarks. The relative ratio between four-cylinder and six-cylinder engines produced in the last 3 years has changed from being 96 per cent and 4 per cent in 1924, respectively to be 79 per cent and 21 per cent respectively in 1926.

Commenting on six-wheel vehicles and on the statements made by Mr. Froesch, Mr. Herrington said that it is necessary for the industry to use every means possible to educate the regulative officials of the States to recognize the additional axle as a means of reducing road-impacts. Otherwise, he said, regulative legislation will break down the heavy load into lighter loads and more of them. Statistics that Mr. Herrington had prepared showed that the ¾-ton truck represented 14 per cent of the units produced in 1924 and only 4 per cent in 1926. In comparison, the 1-ton truck advanced from 72 to 77 per cent from 1924 to 1926, and the 1½-ton truck from 4.9 to 8.9 per cent.

The extent to which legislation has affected the larger sizes of truck is best indicated by the following figures, according to Mr. Herrington. The 2 to 2½-ton and the 2½ to 3½-ton sizes remain practically the same as to the number of units produced for the 3 years, 1924 to 1926. The 3½ to 5-ton units have fallen off from 0.6 to 0.5 per cent of the units produced, and the 5 to 5½-ton sizes have come down from 1.9 to 1.4 per cent. Regarding the cost of operating trucks the speaker said that, considering the average for all trucks, while maintenance costs average 3 per cent of the total cost of operation of the truck that runs 1000 miles per year, they represent 16 per cent of the cost of operation if the truck runs 10,000 miles per year. In conclusion, Mr. Herrington said that the average truck in the United States runs only an average of 26.3 miles per day, a surprisingly low figure.

ALUMINUM PISTONS DISCUSSED

G. D. Welty Tells Buffalo Section of Improved Design and Production Methods

Developments in the art of casting and heat-treating aluminum alloys within the last 6 years and in the design of aluminum pistons for internal-combustion engines within the last 2 years have resulted in the production of pistons that are close grained, free from porosity and blow-holes, have

a Brinell hardness as high as 160 and will run at smaller clearance than any other piston that has yet been produced. These statements were made by G. D. Welty, laboratory research engineer of the Aluminum Co. of America, at the monthly meeting of the Buffalo Section the evening of March 1. P. B. Jackson presided and much interesting discussion was given by those in attendance following the reading of this, the only paper presented at the meeting.

Aluminum alloys that are used for pistons and that contain approximately 90 per cent of aluminum and 10 per cent of copper have, in addition to desirable properties possessed also by cast iron that is used for pistons, a specific gravity only about one-third that of cast iron, said Mr. Welty. The advantages of light-weight pistons are so great, especially in four-cylinder engines, that some of the largest builders of four-cylinder cars almost owe their success to the performance they have been able to obtain by the use of these pistons. In six-cylinder construction the aluminum piston greatly smoothes out the vibration, while in the V-type eight-cylinder engine the aluminum piston almost totally eliminates two vibration periods and greatly reduces vibration at the third period.

The high heat-conductivity of the aluminum piston results in a cooler engine-head and, as a result, the engine can be operated with a higher compression-ratio; 5 to 1 is a fairly common ratio. The lower head-temperature also results in better lubrication and decreased carbon formation, which mean less preignition, cleaner and cooler oil and cooler bearings. These are the chief advantages that are possessed by the aluminum piston.

Aluminum, however, has a coefficient of expansion which is more than twice that of cast iron. This characteristic has been the chief obstacle to general adoption of the aluminum piston and a great majority of the thousands of patents issued on such pistons deal with some means of overcoming this difficulty but only a few of the designs have been commercially successful, he said. Although the high coefficient of expansion has hindered the adoption of aluminum pistons, the improvement in the art of casting aluminum alloys has had a larger influence toward their general adoption, and since 1920 between 25,000,000 and 30,000,000 have been made in this Country by casting in permanent molds. Pistons produced by this method can be duplicated almost exactly, dimensions can be held within very narrow limits, and the pistons are hard, close grained and possess excellent machining properties.

Improvements in the heat-treating process have also played an important part in the success of aluminum pistons by giving them a hardness more than double that of the sand-cast pistons. This hardness gives better machining properties, the metal provides an excellent seat for the piston rings, and the problem of ring-groove wear has been almost eliminated. The metal is much more resistant to skirt wear on the piston than any previously developed and the heat-treatment process also functions as a remover of the strains that were present in the piston as a result of the casting process.

Insert-Type Piston Permits Smaller Clearance

To meet the demand for closer clearance, the insert-type of piston has been developed within the last 2 years. This is like the split-skirt design, which has two bearing-faces with an arc of about 90 deg. each and horizontal slots that separate them from the piston-head, but the insert type may or may not have a vertical slot in one bearing-face to compensate for the excess expansion of the aluminum over the cast iron. It does, however, have two steel inserts that extend from one bearing-face to the other on either side of the wristpin boss. These act as spacers between the bearing-faces and prevent excessive expansion. If the inserts are of cold-rolled steel, the piston can be fitted to about the same clearance as a cast-iron piston of the same diameter, but if made of invar steel, which contains about 35 per cent of nickel and does not expand within the temperature range in the usual engine, the piston can be fitted with a clearance of only slightly more than 0.0005 in. per in. of the diameter of the piston, or approximately half the conventional clearance allowed the cast-iron piston. Such invar-insert pistons have very long life because they never come into contact with the cylinder-wall due to their own expansion and the steel control-members hold them away from the wall.

More perfect lubrication is required with aluminum pistons than with cast-iron pistons, admitted Mr. Welty, especially in cold weather, but the lubrication difficulty is encountered chiefly in engines lubricated by oil-pumps that are placed on the end of the camshaft and that draw their supply through a suction line which often is restricted to a diameter of 5/16 in. At temperatures of from 0 to 10 deg. fahr. the oil, if not diluted, becomes of about the consistency of vaseline, with the result that when the engine is started the pistons do not receive any oil for a time. Water resulting from condensation on the cold cylinder-walls also dilutes the oil to such an extent that the pistons are not adequately lubricated.

Manufacturers who adopt aluminum pistons should fit piston-rings with about 0.0015-in. clearance in the grooves, said Mr. Welty, because when the pistons are cold the grooves contract and if the clearance is much less the rings will be held away from the cylinder-walls and blow-by may occur and cause an explosion in the crankcase.

Experimenting with Magnesium-Alloy Pistons

Magnesium has the advantage over aluminum in that it is from 30 to 40 per cent lighter, but it has no important advantage so far as heat conductivity is concerned. Its development as a piston material will be retarded by the fact that the processes for its reduction and casting are not yet highly perfected, but it has desirable qualities and the engineering

SCHEDULE OF SECTIONS MEETINGS

APRIL

5—Buffalo—Magnesium—S. K. Colby
6—Milwaukee—Modern Airplane Powerplants—L. M. Woolson
7—Detroit—Subject and speaker not announced
8—Southern California—Lubrication—T. Ott, H. L. Dickey and John C. Handy
12—Chicago—Traffic—Carroll E. Robb
Pennsylvania—Traffic Problem—Harold M. Lewis
14—Indiana—Chromium Plating—C. R. Umphreys. Engineering Relationship to Production—George Freers. Fabricating the High-Grade Motor-Car—Max Thoms and W. K. Swigert
18—Cleveland—Air Travel as a Practical Means of Transport—Paul Henderson
21—Dayton—Recent Developments in Lighter-than-Air Craft—Dr. Karl Arnstein
Detroit—Subject and speaker not announced
Metropolitan—Highways and Vehicles—Dr. T. R. Agg and O. T. Kreusser

world will continue working on the metal until eventually some successful installation of magnesium pistons will be made.

Oil Refiners and Engine Design

That oil refiners do not have some voice in connection with the design of gas engines is unfortunate, for several changes would be made if they had, declared Eno Kimball in opening the discussion. Most of the wear on pistons and all internal moving parts of the engine occurs at the time the engine is started. The company with which he is connected, he said, always has endeavored to fit the oil to the engine but has advocated that the surfaces of the engine make it possible to use in cold weather an oil that has a low cold-test and also high lubricating value. The company believes it has such an oil and Mr. Kimball has proved it to his own satisfaction, he said, in his own car which has aluminum pistons. After driving this 27,000 miles, the skirt wear on one of the pistons was a trifle less than 0.002 in. An oil that will flow freely at temperatures of from 0 to 32 deg. fahr. is desirable. Some oils that have a cold test of from 35 to 40 deg. fahr. do not give as much service as customary oils but do flow freely at zero temperature.

Cause of Piston Slap

Chairman Jackson stated that an investigation which he made on piston slap showed that at each revolution of the engine crankshaft the piston moves from one side of the cylinder to the other four times, due to gas pressure and inertia forces, and the inertia forces are greater than the gas-pressure forces when an aluminum piston is working at 3500 r.p.m. He asked Mr. Welty what piston clearance, regardless of material, is necessary to reduce piston slap to a negligible factor and what proportion of the heat of the explosion that is not used as power is conducted away by the pistons and by the piston-rings.

Regarding piston-slap, Mr. Welty said that only one of the four piston oscillations per revolution results in a slap and this occurs when the piston rises on the compression stroke and is snapped over against the opposite side of the cylinder as the crankshaft goes over dead-center and the explosion occurs. At high speed the piston is hot and its expansion reduces the clearance, hence the piston-slap should be less pronounced. Fully as much heat is conducted out through the rings and piston skirt to the cylinder-walls as is radiated from the piston to the oil in the crankcase, he thought.

If aluminum pistons are as good as they are believed to be, what prevents development of aluminum piston-rings backed by steel expanders? inquired Mr. Bassett. In reply Mr. Welty pointed out that such rings would be expensive, as they would require double the number of pieces and the spring backing would require deeper ring grooves, which would necessitate more stock in the piston-head. It is doubtful, also, if aluminum rings could be cast successfully; the most promising method would be to forge them, as aluminum forging has made great advances within the last few years.

Depth and Width of Piston-Rings

Percy Best inquired regarding the best width of ring in relation to piston diameter to give good functioning and low ring-pressure on the cylinder-wall. Mr. Welty answered that the tendency now is to use ⅛-in. rings in aluminum pistons up to 3½-in. diameter and perhaps to use four rings, which admits of the use of an oil-control ring and leaves three compression rings. The narrow rings have less tendency to tighten in the grooves in cold weather than wider rings; they also follow slight irregularities in the cylinder bore and reduce the pressure per square inch.

Commenting on a point raised by Mr. Webster, the speaker admitted that the invar piston affords less opportunity for heat dissipation than the all-aluminum piston with its heavy connection from the wristpin boss to the bearing-face but more heat is dissipated through the aluminum piston-head than through the cast-iron piston-head and more heat goes out through the skirt of the piston.

AIRPLANE CARBURETION AND IGNITION

Latest Developments Explained to Detroit Section by L. S. Hobbs and T. Z. Fagan

How airplane-engine developments, such as the production of V-type and radial engines and superchargers, have made new demands upon carbureters and magnetos, and the ways in which these have been or are being met by the designers, were told at the March 10 meeting of the Detroit Section by L. S. Hobbs, engineer of the Stromberg Motor Devices Co.; and T. Z. Fagan, vice-president of the Scintilla Magneto Co.

Prior to presentation of their papers, L. M. Woolson, who presided as chairman, introduced Lee Chambers, a wartime ace who is now engaged in operating a commercial airline in Florida. More than 300,000 miles per year are being flown, said Mr. Chambers, with an on-schedule record of more than 90 per cent over a period of 9 months. Part of the failure in performance is due to hurricanes and a small part to fog, but the major reason is lack of money. The time is coming, however, when the business man will realize that he is taking no greater chance when he invests in commercial aviation than in any other business enterprise. Some airlines are now showing handsome profits, he said, and almost every airline has improved equipment coming through. In a relatively short time every airline that is managed sensibly will show a reasonable return on capital. Although many problems in aviation remain to be overcome, the lack of finances is the greatest obstacle to development of commercial aviation. The most important requirements for increasing safety of operation are perfected means of navigation and full and frequent reports on weather conditions at terminals.

Another visitor who has distinguished himself as an aviator, Major Schroeder, was also introduced.

How Engine Developments Affect Carbureter Design

A number of aircraft carbureters of different types and a series of a dozen lantern slides were exhibited by Mr. Hobbs in connection with the presentation of his paper on Aircraft Carbureters.

Trend in aircraft-carbureter design depends, he said, upon (*a*) refinements in carburetion, which are to some extent under control of the carbureter designer, and (*b*) the form that advancing engine and airplane development assumes, over which the carbureter designer has no control. The engine design and, remotely, the airplane scheme, determine the shape and size of the carbureter, while the carbureter rquirements govern the interior construction. In practice, the carbureter is built into the least possible space.

The orthodox constant-head suction-metering carbureter usually assumes the form of a combination of float-chamber, venturi restriction and spray nozzle. Several experimental devices designed to replace this type are under construction, however, and some are now undergoing test. Fuel injection is receiving much attention and various schemes for metering and distributing rich mixtures of air and fuel in ratios from 1 to 1 to 1 to 4 or 1 to 5, with the addition of more air at or near the individual cylinders, are proposed.

The most marked external change in carbureters in the last few years is reduction of size with relation to capacity. Increase in the horsepower of water-cooled V-type engines by enlarging the intake-system, increasing engine-speed and enlarging the cylinder bore has necessitated an increase in the size of the carbureter while decreasing the available space for the carbureter in the engine V. Air-cooled radial and V-type engines have both worked toward a single carbureter for the entire engine, due primarily either to rotary induction or to supercharging. With non-pulsating air-flow the maximum efficiency of the carbureter as regards capacity is obtained, but an added complication has been introduced by the necessity for a mechanically operated device to enable a change to be made from a fairly rich mixture at full throttle to a lean mixture for maximum economy at cruising speeds. Although the carbureter has decreased in

size relative to capacity, it has increased in relative weight, due to the addition of economizers, packing glands to provide for supercharger pressure, larger float mechanisms and chambers, and the use of stronger and heavier metal in the throttles and shafts.

Improved Airplane Performance Makes New Demands

Improved airplane performance also has affected the carbureter in several ways. Flying at steep angles and sudden changes in direction have necessitated radical changes in float-chamber construction and in the method of taking fuel from the chamber to the discharge nozzles. Loss in flywheel effect of the propeller due to increased engine-speed and the use of lighter propellers has added to idling difficulties, as finely adjusted mixtures are required together with accurate throttle-fitting and synchronization if more than one carbureter is used on the engine. In this connection it seems that a field of considerable size exists, said Mr. Hobbs, for development of a satisfactory automatic spark-advance for aircraft use.

Extra control of fuel feed must be provided to correct the enriching of the mixture at high altitudes due to decreased density of the air. Formation of ice in the intake-manifold consequent upon the more general use of air-cooled engines and rotary induction-systems, or the supercharger, presents another problem. A short vertical hot-spot immediately above the carbureter offers the best solution, in Mr. Hobbs' opinion. Rotary induction-systems and superchargers work-in especially well with respect to vaporization of the fuel, as maximum power is under control of the designer and the temperature rise through the system is automatic in aiding vaporization.

Several special induction-system or carbureter constructions seem possible and practical for the future. One is the incorporation of a means of utilizing waste hydrogen valved from dirigible airships. As antiknock compounds come into general use, it may become necessary to mix them with the fuel only as required for full-throttle operation. Also, carbureters may be built in two general classifications, (*a*) military and (*b*) commercial.

Magnetos for 8, 9 and 12-Cylinder Engines

Magnetos now in production for aircraft engines of 8, 9 and 12 cylinders, both V-type and radial, were described in detail by Mr. Fagan. The standard design has the minimum quantity of iron in the rotating magnet that is necessary to produce a spark of sufficient intensity to fire any fuel at a compression ratio consistent with modern engine practice. At 50 r.p.m. it produces 0.007 joule and at 2000 r.p.m. produces 0.076 joule. A flaming hot spark is neither necessary nor desirable; it is destructive of the spark-plug electrodes and makes too great a draft on the magneto. Moreover, experiments at the Bureau of Standards have shown that if the spark energy greatly exceeds 0.00025 joule, the rate of flame spread in gaseous mixtures, and hence the power of the engine, is unaffected.

A new type of spark-plug cable is now in service, said Mr. Fagan, that is encased in a woven covering impregnated with a special preparation that is impervious to water, oil and kerosene and that, by virtue of its dielectric qualities, lessens corona discharge materially. For satisfactory completion of the ignition process, the magneto manufacturers look to the spark-plug makers. An unusually small plug has been developed by Roy T. Hurley, with the cooperation of the material section of the Engineering Division of the Air Corps at McCook Field and the Bureau of Aeronautics, and is now being used by the Navy. This greatly relieves the congested condition in the V of the 12-cylinder water-cooled engine and thus lessens the fire hazard created by proximity of exposed spark-plug terminals to other parts of the engine.

Interference with the radio has been traced to the primary and secondary circuits of the ignition, and to eliminate the interference, the spark-plug cables are bunched and shielded with thin sheet-steel and metallic braid grounded to the engine at frequent intervals. This, however, introduces troublesome insulating problems associated with excessive leakage of current.

The standard-magneto performance is satisfactory, in general, at altitudes up to 18,000 or 20,000 ft., but some difficulty is presented at greater altitudes with supercharged engines, as the reduction of sea-level air-pressures allows the high-tension current to jump to the ground or to other convenient points within the magneto. Both McCook Field and the Bureau of Aeronautics are much interested in this problem, stated the speaker, and are making tests with a pair of magnetos in which the latest modifications are incorporated.

The present design of contact breaker used in the standard magnetos is the outgrowth of trials of more than 100 different breakers of various designs and is of the rocker-lever type.

Vertical Double Magneto Saves Engine Weight

Engine weight amounting to from 15 to 20 lb. is saved in the V-type by a double vertical magneto that can be placed between the banks of cylinders. This consists mainly of two coils that receive their flux from a single four-pole rotating magnet and two breaker levers operated by a single four-lobe cam. Should one side of the magneto fail mechanically or electrically, the other side will continue to supply sparks to one set of plugs. This type has passed a bench-test of 250 hr. at 3000 r.p.m. and 50 hr. on a Curtiss D-12 engine.

L. M. Woolson Thomas Z. Fagan
The Chairman (Left) and One of the Speakers (Right) at the March Meeting of the Detroit Section

Operating conditions of the radial air-cooled engine are in some respects less severe upon the magneto than are those of the water-cooled V-type, said Mr. Fagan, who, however, strongly recommended adequate protection of the magneto by cowling. Magneto temperatures in excess of 160 deg. fahr. lower the electrical efficiency of the primary winding and consequently the spark value of the secondary. The period and amplitude of vibration of certain water-cooled V-type engines have a destructive effect on the contact breaker when running dynamometer-tests, which impose much more severe temperature and vibration conditions upon the magneto than does actual service. A problem is now faced of building some magnetos to withstand exaggerated vibration.

Careful consideration of magneto mounting and method of drive is of great importance, according to Mr. Fagan, who said that a satisfactory arrangement with a 90-deg. V-type engine that has excessive vibration will be to mount the magnetos parallel to the crankshaft, as close as possible to the center of gravity, and drive them through spur-gears with a flexible coupling on the magneto shafts. The present type of magneto mounting will soon become obsolete and it is believed that in time the mounting will be built into the engine crankcase and the rotating-magnet bearings will receive their lubrication much the same as the crankshaft bearings do.

Provision within the magneto for distribution of high-tension current from an external source has almost eliminated the necessity for low coming-in speeds for starting, hence smaller magnetos with a weight reduction of about 4 lb. over present types can be considered.

Questions in Discussion Bring Out More Facts

Answering question cards, Mr. Hobbs said that carbureters are rated as to capacity by the diameter of their barrels, all of which are of S.A.E. Standard; that it is not known how much heat is required to prevent ice formation but the main requirement is to keep it from forming on the wall in large pieces that will not go through the carbureter; that the ratio of gas-impeller speed to engine-speed depends upon the type of installation, the ratio for superchargers being 12 or 14 to 1 while rotary inductors usually turn slowly; that aircraft-engine manifolds operate colder than automobile-engine manifolds because aviation gasoline is of better grade than automobile gasoline but is becoming poorer and poorer and the engine builder designs the manifold to use the mixture as cold as possible to save every possible ounce of engine weight; that the idling speed of an engine depends upon its maximum speed, and with the maximum speed of from 2250 to 2500 r.p.m. the idling speed can be as low as 200 r.p.m.; and that with supercharging at atmospheric pressure and temperature a limit exists to the richness of a mixture that will be combustible without detonation, but this will go up slightly as the temperature is lowered.

Mr. Fagan stated in reply to question cards that cams for timing the spark must be accurate within 2 deg., and that standard magnetos will produce a satisfactory spark when operating at temperatures of 180 or 185 deg. fahr., although the strength of the spark is lessened considerably.

CLEAN LUBRICATING-OIL A NECESSITY

Northern California Section Features Oil-Cleaners and Holds Surprise Party

An extensive program was unfolded at the meeting of the Northern California Section that was held on March 17 at the Athens Athletic Club, Oakland, Cal. A dinner preceded the technical session and there was a large attendance at the meeting. Oil-cleaners was the subject of two papers, one by Charles W. Winslow, consulting engineer, and the other by W. W. MacDonald, manager of the W. W. MacDonald Co., San Francisco. A paper on Economical Trailer Operation was also presented by A. Scott, and a fourth paper on the New Fageol Motorcoach was read by Frank Fageol, of the Fageol Motors Co., Oakland. A surprise entertainment was also a feature.

In the course of the discussion following the presentation of the papers, Prof. Llewellyn Boelter, of the experimental-engineering department of the University of California, gave a very interesting talk on the head-lamp problem, showing the relation of head-lamp construction and the degree to which the road is illuminated to accidents caused by motor-vehicles. Other interesting features of the discussion had to do with the dilution of crankcase oil by fuel, and with the rectification and filtration of lubricating-oil.

OIL-ENGINE-CAR RACE POSTPONED

Addresses on Heavy-Oil Engines Draw Large Attendance at Indiana Section Meeting

The keen interest that is taken in heavy-oil engines was underestimated by half when dinner arrangements were made for 45 members and guests for the Indiana Section meeting on March 10. The number that sat down to dinner in the Severin Hotel, Indianapolis, was 83, and 200 attended the technical session that followed to hear papers and addresses on the subject.

Before the first speaker was announced, Chairman Ralph R. Teetor called for a vote on the proposal of the Society to include in the Indiana Section membership territory the following counties within commuting distance of Indianapolis: Marion, Hendricks, Shelby, Boone, Johnson, Hancock, Morgan and Hamilton, and the City of Anderson. A motion to this effect was put, seconded and carried. An announcement was made immediately before adjournment that the next meeting of the Section will be a production meeting, the first to be held by the Indiana Section.

Why the Race Was Deferred

The proposed race for cars driven by oil-engines has been abandoned for this year, T. E. Meyers, manager of the Indianapolis Motor Speedway, told the meeting, but it is likely that at some early date an announcement will be made of a future date for such a race. The reason for the postponement is that a race next fall would not allow sufficient time to formulate rules that would be fair and practical and for engineers to design and factories to build cars to compete in it. Although only one newspaper notice of the contest was published, said Mr. Meyers, it provoked much interest and wide comment, which gives rise to the hope that the Indianapolis Motor Speedway will, before long, promote the pioneer contest for oil-engine motor-cars.

A set of tentative rules for the proposed race sent to a number of builders of this type of engine in this Country and Europe elicited a number of comments and recommendations that indicated the need for extensive modification. Some of these, which were read by Mr. Meyers, pointed out the importance of (*a*) providing in some way to give advantage to the engine that shows low fuel-consumption, light weight, high speed and flexibility; (*b*) imposing no restriction on the use of ignition systems, as this would tend to limit the speed and flexibility of the engines and be reflected in greater bulk and weight; (*c*) providing a limitation on piston displacement per unit of time, but not on displacement alone, so that designers can select an efficient engine-size with relation to economy, speed, weight, cost and other factors, such as adaptability to heavy vehicles; (*d*) classifying and handicapping the cars on the basis of cost of construction, cost per horsepower-mile to drive a specific weight as related to piston displacement, simplicity of operation and control and flexibility; (*e*) defining by specific gravity the fuel oils that may be used, as for example, oils of not higher than 24 deg. Baumé; (*f*) specifying the maximum and minimum wheelbase and tread; and (*g*) indicating the character of the cars by some more definite term than "oil-burning cars," which may be construed as including cars that burn oil to generate steam. These and other suggestions and comments convinced the Speedway management that much time will be required to study the subject and prepare a set of rules that will promote development of the oil engines along the most desirable lines.

Oil Preheated before Injection

After describing the four general types of injection now employed in heavy-oil engines: air, solid fuel, gas and the Cummins method of injection, C. L. Cummins, president of the Cummins Engine Co., explained in detail his system, which he said is hard to classify, and showed nine lantern slides with his address. The company was interested primarily in small, high-speed light-weight engines and after 5 years of continuous development perfected an engine that has been in constant production for the last 3 or 4 years and that is operating under all climatic conditions from those in the Arctic Circle to those at the Equator and in the hands of Esquimos, Indians, Japanese, Greeks and Creole fishermen.

His method of injection to make high engine-speed possible, as described by Mr. Cummins, consists in providing an annular space between two sections of the atomizer cups in the injector and allowing each successive charge of fuel to remain in this space during 720 deg. of crankshaft rotation in a four-cycle engine, that is, throughout one cycle of compression, combustion and exhaust strokes. The waiting charge in the annular space is subjected to heat transferred through

(*Continued on p.* 509)

A Comprehensive Apprenticeship Program for the Automotive Industry

By H. A. Frommelt[1]

Annual Meeting Paper

Illustrated with Photographs

ABSTRACT

FOLLOWING his statements that apprenticeship in in the automotive industry is not only a possibility but an actuality and that the results have proved its necessity and value, the author remarks that one of the greatest future developments in the automotive field will take place through the training of personnel and says that the effect of a comprehensive and adequate program upon the industry as a whole is certainly more than a matter of speculation. Apprenticeship for the most neglected field, that of service, rests largely with the impetus of an example set by the manufacturer, in addition to the actual support of such a program. Outstanding examples of success of personnel training in the automotive field prove by facts the possibility of a comprehensive application of apprenticeship, and the following results can be expected from an adequate program of training:

(1) A sufficient number of toolmakers, machinists and die-sinkers
(2) The creation of a supply of trained personnel that can be shunted into engineering, drafting, servicing and supervisory departments and positions as needed
(3) The stabilization of the working force
(4) The reduction of turnover; the saving effected in this manner should in itself compensate for the cost of training
(5) The formation of the best defense against adverse economic doctrines through the education of the backbone of an organization
(6) The key to unlock the most fertile field in the automobile world; namely, adequate servicing of cars

In addition to an elaboration by representative speakers of points made in the paper, a special feature of the discussion is a description of Army personnel-training at Camp Holabird at Baltimore.

THE unmistakable trend in American industry during the last few years toward a sane program of industrial education has not obviated the necessity of meeting certain criticisms leveled against this comparatively recent development. In many quarters well-defined prejudices that have been born of a century of disregard for formal apprenticeship still exist. Moreover, in many instances the recognition of the need of apprenticeship is matched by a deep-rooted suspicion that perhaps, after all, industrial training under modern conditions is impossible, uneconomical and even, as such, unnecessary. "Perhaps," and thus runs the unconscious mental process only too frequently, "we have outrun the necessity for a formal apprenticeship; perhaps there is some other escape from the obvious dilemma of a scarcity of skilled personnel, other than the laborious and irksome process of training on the job." Thus, before laying down the outlines of an apprenticeship program for the automotive industry too confidently, it may be well to meet the more common objections set up against a formal program of training.

Unfortunately, there are still those who meet all comers heralding apprenticeship with the ill-considered statement "We can go out and hire what skill we need." But it must be obvious to even the most slothful minded that, if this policy were universally adopted, there would soon come an end to the supply of skill to be hired so easily and gratuitously. However, the most effective of the arguments is that presented by harsh, cruel facts. Unless one is satisfied with the self-anointed "mechanic" it is no longer possible, except in unusual circumstances and times, to "go out and hire the skill required."

In this connection it is well to consider for a moment the asininity of this policy, only too commonly pursued even at present, in the light of an illustration. There will only be a sufficient supply of horses for all needs if colts are raised to meet the demands. If farmers were to set aside all the disagreeable features of breeding and raising colts, going forth with the determination to "buy what they need," it is patent that soon there would be none to buy and the diminishing supply would naturally increase the price. We cannot continue long on the theory that paying more for a horse increases the supply of horses. Yet this is what we have been doing in the field of apprenticeship.

Induction of Youth into the Trades

Perhaps the most common objection against apprenticeship and the one most frequently voiced runs as follows: "The American boy of the present day will not work at a trade in a shop, where grease and overalls are only too conspicuous." The corollary of this objection is that "the boys of today are all rushing into the white-collar jobs." The most effective argument against this objection is, as always, a citation of facts. Young American boys are being inducted into trade shops, in localities where apprenticeship actually has been tried, in sufficient numbers for all needs. Even into the foundry, admittedly a department with a disagreeable exterior, it is found possible to attract young Americans to apprentice themselves with the sole thought of learning the foundry trades, such as molding and coremaking.

Young Americans *can* be inducted into the trades. They *are being* inducted into the trades. Wherever the experiment has been tried, this is the one outstanding fact that skeptics must first of all admit. Moreover, in some localities apprenticeship has been tried long enough so that there can be no question but that this commonly cited objection is, after all and particularly after a whole-hearted and intelligent application, no objection at all. But perhaps it is true that modern American youth has an undue hankering for the "white-collar job." To any intelligent observer it is obvious that these youngsters are not so much *rushing into* the white-

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collar jobs as they are *rushing away from* the conditions of training in our shops and their trades. Experience has proved that we are not to suspect apprenticeship when an industrial executive has announced "We have tried apprenticeship and it has failed," but rather his application of it, or his ideas as to the constituent elements that must enter into a successful apprenticeship program. The fact is, and this again from experience, that if apprenticeship is made more an education in industry than a mere job, it will and does attract our American young men as apprentices and holds them on into journeymanship years.

Perhaps another very specious corollary to this objection that young men of today will not be apprenticed is the statement that finds a ready nodding of heads: "The present generation is almost unanimously going in for higher education." Americans worship at the altar of classroom education and this objection is supposed, therefore, to present the final unanswerable argument. For no one dare contend that our youths should be taken from school, even high school, and made to "learn a trade." Not infrequently this is the very objection raised against apprenticeship among the school people. In fact, no thoroughgoing training program, worthy the name, has ever set out to attract from school young people who should continue there. It merely presents a welcome to the young person leaving school, whether that departure takes place from grade school, high school or college.

However, there is little to fear from the bogy of "too much higher education." Here, again, facts are deadly. The United States Bureau of Education recently released some significant figures as regards the "spread" of education in this Country. For every 100 children, male and female, in the sixth grade, only 67 graduate from the eighth grade. Of these 67, only 34 enter high school, and but 14 complete the 4 years. Seven of these 14 enter college and but a beggarly 2 graduate. Surely this is a sickly and unsubstantial dread that our objectors are allowing to upset their equilibrium. A defection of 33 per cent even in the grades, where somehow we had suspected a 100-per cent attendance. Only 50 per cent of those who graduate from the eighth grade enter high school, and less than half of these remain to complete the course. And the percentage entering and leaving college is even more disconcerting. Surely we are far removed from a surfeit of education, if such even were possible. Moreover, and this should be put down with no little emphasis, apprenticeship is not looking forward with fear and trembling to the time when so-called higher education shall become more widespread. Apprenticeship does not deal in mental misfits and unfits. Everything else being equal, the more classroom education there is, the better is the apprentice. Again, apprenticeship is not a form of education competing with our traditional schoolroom education. It is merely a method of helping the young man complete his education, no matter when he leaves school, be that grade school, high school or college. Apprenticeship meets the young graduate, conducts him through industry in an orderly supervised manner and presents to him a definite objective after a few years of preparation and training. It is a supplement to our classroom training and is intended to bridge the dangerous gap between the period of schooling and that of livelihood.

Not infrequently, modern production-methods are pointed to as evidence that apprenticeship is today unnecessary; specialists, machine operators, semi-skilled employes, rather than the trained mechanic, are necessary under modern methods of production and manufacture. No other argument against industrial training is more specious. In fact, it might be said that the net effect of mass-production methods has been and always will be to increase the demand and the necessity for skill and training. More skilled mechanics are required today, both relatively and absolutely, than ever before in the history of the world. And all this in spite of production methods and the machinization of our industrial operations.

Effects of Mass Production

The automotive industry is the classical example of mass production and the one to which the enthusiasts of this argument always appeal. Therefore, it will be well to examine this argument a little more closely. The argument falls down at every turn. In the first place, within the industry itself a whole army of toolmakers, die-makers and die-sinkers and other mechanics of like nature who require the highest kind of skill, are necessary every day. Second, any industry machinized as is the automotive industry requires a relatively large number of maintenance and machine repairmen, who must at least be skilled machinists. Third, it is a commonplace and everyday fact that an industry organized as is this one requires a larger number of supervisory personnel than it would if otherwise organized. And who will say that he is willing to draw entirely from among the untrained for inspectors, gang foremen and foremen? Fourth, the special equipment and machines demanded by the automotive industry have in turn drawn upon the upper levels of skill in this Country for the creation and manufacture of this equipment. Fifth, the product of automatic machines cannot, unfortunately, be repaired and serviced by either automatic machines or automatons. The product of the automotive industry requires a skilled personnel for its proper and efficient servicing. The industry is, to be sure, notoriously undermanned in skill, yet the plain fact is that at present more mechanics are required in this department of the business than in manufacture. But they are not being trained; we are content to accept so-called "service" in the most disgraceful hoax that has ever been perpetrated upon an entire people.

Whichever angle we examine, we are confronted with a set of facts which make the conclusion that more mechanics are needed today than ever before inevitable and inescapable. In the case of one of the largest tire and rubber companies, we find that 1200 mechanics of the highest rank are necessary to service, repair and install the equipment, buildings and machines necessary for the production of tires and mechanical rubber-goods. This personnel does not represent direct labor in any manner. With 25,000 employes on the roster, we are confronted with the interesting and significant fact that 1 man in every 20, approximately, must of necessity be a skilled mechanic. If we add to this the number of tire-making mechanics and trained personnel generally required, this ratio would be doubled. And all this is in spite of the fact that the tire industry is above all else an exponent of mass production.

All that has been done, generally speaking, through the machinization of industrial operations and mass production, so far as the personnel is concerned, is to raise the common laborer from the status of an unskilled worker of brawn to that of a semi-skilled machine-operator. For the rest, we have increased the need, demand and necessity for skill and training immensely, both relatively and absolutely. Never before in the history of

the world has there been such need for industrial skill and mental and manual dexterity as at present. And the automotive industry is at once one of the prime causes and the most needy member of the industrial family.

Apprenticeship is necessary for the life and health of American industry. The economic changes wrought by the World War, the immigration policy upon which, as a Country, we have entered, and changes with industry itself are forcing us back upon the "training-on-the-job" method to produce the skill without which we shall be a bankrupt industrial-nation in a personnel sense. This can be done; it *is* being done, under modern conditions to meet a modern demand.

Industrial Training Program

What, then, are the nature and content of a successful industrial training-program such as will meet this obvious demand for skill and training and produce results efficiently and economically? Apprenticeship, rightly considered, is but a synonym for an industrial education; a training in some branch of industrial activity. Considering this interpretation for a moment, it is obvious that, if accepted, we must have teachers, pupils and subject matter. In other words, there must be apprentices to be taught, a teacher or group of teachers to do the teaching, and finally a body of manual operations and related theory as subject matter; or again, apprentices, instructors and a definite trade-objective.

This rather academic consideration of apprenticeship has one advantage at least in that it immediately separates chaff from kernel. Thus, there is no apprenticeship when a young man is not working according to a schedule of shop operations that is commonly considered to represent the important or basic operations of the trade in mind. There is no apprenticeship unless it is definitely understood throughout the industrial organization that there is some actual instructing to be done and that this responsibility rests largely upon a certain group. Finally, there is no apprenticeship unless related teaching is being given separately and apart from the instruction in the manual phases of the trade work. In other words, a body of facts and theory must be taught over and above the actual shop-operations, since it is impossible, under ordinary shop-conditions, to teach related theory, shop mathematics and sketching, "on the job." This is formal apprenticeship in theory and without application to any particular industry. In fact, some form of apprenticeship has always been in vogue. It is impossible to employ in the lowliest kind of a job a man off the streets without doing some teaching and training and therefore putting into effect some sort of apprenticeship.

But this is a brief for formal apprenticeship, a program of training in which the management enters wholeheartedly, a program that builds up a tradition of respect and cognizance about it among the members of the shop organization, a program that is supervised and executed as diligently and religiously as any production program and recognized as of as much importance. We have here chosen to set this sort of formal apprenticeship off against the casual type, largely because the latter has failed utterly to develop the quality and quantity of skill necessary for our further vigorous industrial livelihood.

What, then, are the essential factors that enter into a "going apprenticeship"? They can be listed as those of tradition, of education and of solidarity.

Tradition

Apprenticeship can be conceived as successful throughout a community only when every element in that community regards apprenticeship as an essential step in the industrial life of its people. When vocational lanes have been drawn through the industrial and commercial bailiwicks of the community and clearly marked; when these lanes are extended to the very doors of the community's schools; when parents and teachers believe that an apprenticeship is a necessary complement to classroom education, whether that be of grade, high-school or college caliber, then it may be said, with some degree of accuracy, that a tradition of training has permeated the community. And only under these conditions will apprenticeship be an important part of the community's educational life.

Education

Feeding this tradition, in fact being its very soul and life principle, is the factor of education. Apprenticeship must be made synonymous with education. An apprenticeship should be made more of an education than a mere job for the young man engaging in it. The curriculum for an educational program of this kind must consist of the shop and the school schedules, the former to consist of the essential shop-operations that comprise a trade and the latter in the elementary and fundamental technical body of facts and theory that dovetail with the actual manual or shop procedure. Together, these two schedules provide the "educational matter." Obviously, the second factor presupposes an organization to present and to teach the facts and to administer this educational program. This personnel may not differ largely from an existing producing-organization. But the tradition of teaching, of apprenticeship, must be theirs. Even in the larger industrial organizations, where it is possible to set aside a personnel to do shop and classroom instructing, shop executives, foremen and others must appreciate thoroughly and be inclined sympathetically toward an industrial training-program like apprenticeship before there can be the slightest hope of success.

Solidarity

Obviously, from these considerations, there are in any community a vast number of organizations in which the teaching staff and the educational matter would be meager indeed if these were to undertake apprenticeship individually and alone. The fact is that more than 90 per cent of the industrial organizations in this Country employ less than 100 men each. If we add to these the number of larger organizations in which the majority of operations are on a production basis, it must be plain immediately that apprenticeship can never survive a piecemeal and individual-plant application.

Relatively few organizations are of such size or is the character of their work such that they can undertake successfully a worthwhile and adequate training-program. A typical industrial community will number relatively few that can.. Were they to undertake apprenticeship alone they unjustly would become the source of supply of skill for the remainder. Launched as a community program, in which all can undertake their proportionate share of the burden, all, regardless of their size and the character of their work, can participate. Only the application of the principle of solidarity can make apprenticeship successful throughout a community.

To illustrate the necessity of the application of this principle, two examples are referred to:

(1) A survey of a small community adjoining Chicago revealed a total of 14 metal-working plants, only 3 of which employed more than 500 but less than 1000 persons. Only 4 of these 14 organizations could have entered upon apprentice training on

an individual basis, providing places for 94 apprentices. Joining hands and launching a community program made it possible for all to do their share and swell the total number of apprentices to 176, the number required to maintain this community on a self-supporting basis

(2) Likewise, a survey of the "quad-cities": Moline, East Moline and Rock Island, Ill., and Davenport, Iowa, shows the interesting situation in which, of the 45 plants, only 3 can lay claim to doing general-jobbing work. Moreover, but one plant in four communities employs more than 1000 men and these, almost to a man, on mass production. Seven of these manufacturing establishments employ between 500 and 600 men; 3 between 350 and 500; 11 between 100 and 200; and the remainder, some 25 plants, have less than 100 employes each on their payroll

These communities have joined hands through a representative trade-organization and have launched a program of apprenticeship spread over these Iowa and Illinois communities. Without this spirit of cooperation, it is certain that not more than 150 apprentices could have been accommodated; with it, the ultimate possibilities lie near 500 apprentices. Had a few plants engaged upon apprenticeship individually and had they ultimately had in training 150 apprentices, these would have been preyed upon by the remaining plants; it would have been simple to foretell accurately the final result. As it is, all recognize that the business of training men is a community problem and all are doing their proportionate share to provide an adequate supply.

Principles of Training Applied

Applying these principles to the automotive industry results in some extremely interesting findings. The automotive industry passed its majority only a few years ago. Twenty-five years ago there were less than 8000 cars on our highways; today, there are more than 20,000,000 cars. At the opening of the World War, we were building 500,000 cars each year; today, more than 4,000,000 annually. It is trite to say that this is the industrial marvel of the ages. Here we have imagination, fancy and romance in the superlative, but little if any of tradition. The industry itself has been swept along by such gigantic social, economic and engineering revolutions that little conscious leading and directing from within have been possible. Hence, when the indictment is leveled against the industry as such that it has been and is the most malignant parasite on the industrial body, living on the trained personnel of other long-established and basic American industries, the indictment is scarcely just. One might with equal success bring charges against the inanimate and destructive tornado Those who unwittingly and unknowingly unleashed this revolution in the art of individual transportation were soon its victims. They were carried along on the cataclysmic industrial changes that swooped down overnight and were forced whither these gigantic forces led, whether they would or not.

But the period of revolution is over. The day of the routine and the traditional are here. The automotive industry cannot much longer evade indictment for neglecting a fundamental problem in personnel by taking refuge behind the unusual conditions in the industry during the last 25 years. The time has come when this largest though youngest child of the American industrial family must support itself in its personnel aspects. The older members of the family have given much to help it through the hard years af adolescence. With manhood and a rich family-inheritance, it must now proceed "on its own."

Apprenticeship in the Automotive Industry

There are two outstanding phases of this question that we wish briefly to examine in this investigation. First, that of the manufacturing or producing aspect of the business; second, that of service.

In reference to manufacturing, sporadic attempts have been made in past years among automobile builders to install apprenticeship in at least some few of their departments, such as toolroom, maintenance and die departments. But the automotive field is strewn with many abandoned programs. In nearly every instance, unfortunately, the causes must be sought in a changed personnel that was hostile to industrial education. In none that have passed under observation can the charge be made that apprenticeship as such was unsuited to the needs of the automotive industry.

A cursory analysis of the machine department of any automobile building plant makes evident and logical the following objectives for training:

Semi-Skilled Operators
Machinists on Maintenance Work
Die-Makers
Toolmakers
Draftsmen
Set-Up Men
Inspectors
Production-Department Personnel
Time-Study Personnel
Engineering Department
Assistant Foremen
Foremen

The fundamental course for all these, as it happens, is a combination schedule of machine-shop and toolroom. All apprentices would be inducted as machinist apprentices; at the end of 2 years, depending upon individual abilities, predilections and opportunities, some would be shunted into toolmaking, a few into die-making, others into the drafting-room or engineering department to continue as drafting apprentices, while some would continue as machinists. The lower level of the entire group would precipitate out at the end of 4 years as semi-skilled operators. Some of the upper level that continued through the machine-shop and toolroom would be drafted for the production, time-study and engineering departments, whenever skill and training were found to be necessary. A few would continue on as set-up men, inspectors, assistant foremen and foremen, as the opportunities and their abilities permitted.

Hence, while the training program would not in any sense contemplate the "training" of foremen, it would be one of the prime functions of such a program to "uncover" such latent talent. And what better method could be adopted than that of apprenticeship in which young men come under close scrutiny and observation for a period of 4 years? The displaying of leadership and those qualities necessary in foremen will inevitably come to the surface during these 4 years. The actual detailed schedule for the metal-working departments of an automobile building plant need not be set down here as it would vary somewhat with each separate plant.

The same analysis can and should be made for the other departments, such as those for heat-treating, body-building, foundry, and pattern making. In each of these, no matter how machinized the operations, some young men should be in training, if only for supervisory posi-

tions, in which a broad trade-training is generally necessary and always valuable.

Servicing

It is in the service branch of the automotive business that we find at once the most tragic conditions and the most crying need for some form of training. There are at present about 300,000 repairmen and helpers employed in the United States. Of these, 90,000 entered the industry last year. Of this 90,000, less than 20,000 had any special training before employment. Raw recruits to the number of 70,000 were taken into repair-shops last year to learn by the pick-up and the trial-and-error method, a method unsound educationally, uneconomical for the employer and employe alike, and manifestly unjust to the clientele. More men are employed on the method, a method unsound educationally, uneconomical for the employer and employe alike, and manifestly un-270 cars in operation to each service-station or about 60 cars to each service-mechanic. If this ratio is even to hold its own, at least 100,000 men must be trained each year.

Here is a task on which not only the dealer, the garage man, the wayside service-station and the itinerant mechanic must unite for a sane and sensible program for solution, but above all else the automotive industry as such. Each and every element in this giant industrial workshop must be enlisted to lift the curse of neglect, incompetence and misrepresentation from the back of Automobile Service. It is obvious that the majority of competent service-mechanics must have had their opportunity for training in the service garage. The so-called automobile-mechanic schools, while undoubtedly serving a purpose when honestly administered, cannot hope to cope with the problem as such; any more than the technical or trade schools solved the problem of the supply of mechanics in the metal-working industries during the past generation. This is a training that must take place "on the job," though there is much room for supplementary classroom and home-study work in addition.

However, the contention laid down in this presentation is this: The automobile building plants should first set the pace and the standard by having an adequate apprenticeship-program that would supply their every personnel need. The tradition thus established throughout the industry would permeate downward into the service department of the business. If this apprenticeship program were sufficiently wide in scope, a thorough and fundamental mechanical-trade course would be included to train service managers. The regular machine and tool-making apprenticeship provides an excellent foundation for this program and the young men can either be drawn from the regular apprentice group or, what is probably more feasible for this group, taken in from the service-stations upon the recommendation of the local dealer. Each and every automobile builder should provide service managers, expert in the servicing and upkeep of his cars. One need not be a prophet or the son of a prophet to predict that the manufacturer who provides the kind of service the long-suffering public is demanding will receive the only consideration worthwhile from the buyer. Automobiles, within their various classes, differ little in workmanship, material and appointments. The future automobile will be purchased largely on the basis of actual service that the dealer can and will render.

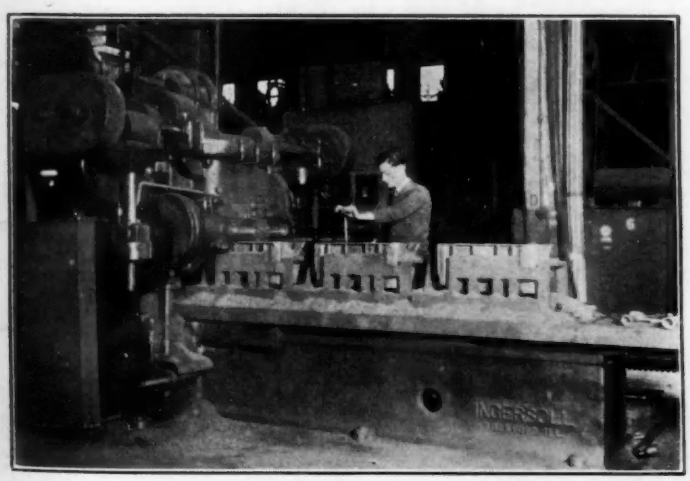

Fig. 1—Typical Apprentice at Work
Apprentices Are Placed in the Regular Lines of Production for the Working-Out of the Shop Schedule

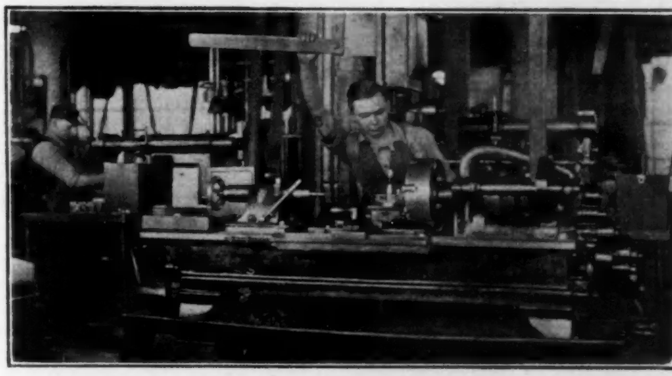

Fig. 2—Student Apprentice Operating a Lathe
The Apprentice Is Turning a Blank for a Milling-Cutter

It is true that some of the discontent of the driving public with the service or the lack of it that is so prevalent today is not actually chargeable to the service department. Automobiles are over-sold; that is, the owner is made to believe by the sales department that the car will do more than the most enthusiastic engineering department ever hoped it could do. In addition, the service is misrepresented. The garage mechanic is sometimes expected to perform miracles. Add to all this a public largely ignorant of engineering values and it can be appreciated readily that service departments are more roundly belabored than they deserve to be.

Yet the plain fact is that the American driving public is face to face with the most incompetent service that even that gullible public has ever had forced upon it. Those manufacturers who first vision the possibilities that lie ahead—as indeed one has years ago—in the field of automobile servicing will have new and fertile fields to conquer.

And the whole of the service problems rests upon an adequate apprenticeship. Aside from the actual palpable and immediate results that apprenticeship would bring about in the automotive field, attention should be called to a somewhat intangible and more remote effect, that nevertheless is a most important desideratum, particularly at this time. A formal apprenticeship over a period of years, usually 4 years, is the very best method of inculcating sound economic doctrine in these future mechanics. A sound course in shop or industrial economics, illuminated by illustrations from the workaday world in which the beginner lives, is the only sensible and effective manner of meeting adverse economic propaganda. Every aspect of apprenticeship, from the youthfulness of the average apprentice to the ease with which a course in industrial economies can be added to the regular curri-

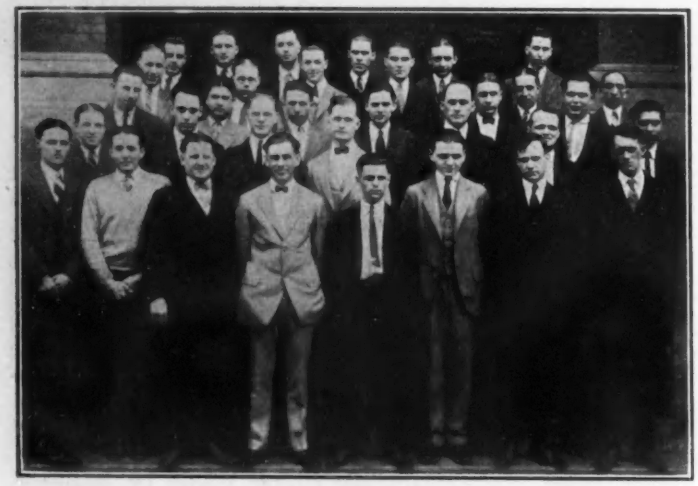

FIG. 3—TYPICAL GROUP OF STUDENT APPRENTICES
The Photograph Was Taken 6 Months before Their Graduation

culum, invites the employer to make the most of the opportunity.

If the automotive industry as a whole would wage the only successful battle against unsound and subversive propaganda, it should make use of a program of industrial education in which facts and commonsense will make a lasting impression upon the young learners. In this manner the key group of the industry will be made economic literates and thus help to stabilize the personnel generally.

One need not remain wholly in the realm of speculation when considering apprenticeship in the automobile industry. Three outstanding examples of well-organized and administered programs are presented herewith with a view to proving, if there be such need, that apprenticeship in the automotive field is not only a possibility based on theoretical considerations but an actuality.

EXAMPLE 1

The Yellow Sleeve Valve Engine Works, East Moline, Ill., is a subsidiary of the General Motors Corporation and has, under the direction of L. Ruthenburg, established an excellent training-program. Apprentices are being placed at work on 4-year machine and toolroom schedules in groups of 12 every 6 months. At present, 18 are employed and the development will continue until approximately 50 apprentices have been placed at work. (See Fig. 1.) The outstanding characteristic of this program is the placing of apprentices in the regular lines of production for the working-out of the shop schedule. This step made apprenticeship possible, as the tool and other departments where mechanics are employed are relatively small and would be incapable of accommodating one-fourth the number now contemplated. Some apprentices will be shunted from the fundamental machine course at the end of 2 years and placed in drafting, engineering, toolmaking and other departments as their abilities and predilections and the opportunities of these departments warrant. The intelligence and enthusiasm that have been applied by this management to the problem presages complete success.

EXAMPLE 2

The Studebaker Corporation of America has, at present, in its South Bend works, 82 apprentices directed by an assistant foreman, a foreman and an apprentice supervisor, in addition to the regular shop-personnel as they come into contact with these young men in training. The program in this instance comprises toolmaking and machine-shop work. The apprentices are routed through the tool and die departments only, their schedule calling for no time to be spent in the production departments. In this instance the tool and the die departments are sufficiently large to accommodate the number of apprentices necessary under present conditions. (See Fig. 2.)

The schedule is of the typical 4-year machinist and toolmaking variety and is incorporated in a contract entered into by the apprentice, his guardian and the company. The Studebaker Corporation has had sufficient experience with apprenticeship and has seen enough of the results of an adequate program so that it is considered a permanent part of the corporation's personnel policy. Dr. Lippincott, the director of the cooperative department, and E. Warrick, apprentice supervisor, are charged with the responsibility of this excellent program.

EXAMPLE 3

The following statistics of the apprenticeship program of the Reo Motor Car Co. are eloquent of the remarkable program established at its Lansing, Mich., plant:

Present Enrollment	192
Number of Graduates	254
Percentage of Graduates Now with the Reo Company	72
Number of Full-Time Instructors	7
Approximate Value of Equipment	$75,000
Graduate Apprentices Now Working at the Reo Plant	
Toolroom	41
Inspectors	17
Foremen	17
Engineering Department	15
Draftsmen and Designers	10
Service and Roadmen	8
Machine Repair	6

A well-equipped vestibule-shop, in which approximately 75 apprentices are accommodated at one time, is a vital part of this program. (See Figs. 3 and 4.) Here, too, as in the case of the Yellow Sleeve Valve Engine Works, apprentices are placed in the production departments during their periods of training.

The outstanding results of this program are stated

FIG. 4—DRAFTING-ROOM CLASS
The Ideal Facilities Provided for the Instruction of Student Apprentices by the Reo Motor Car Co. Are Illustrated

briefly in the foregoing tabulation, but it should be added that the Reo Motor Car Co. has an average turnover of approximately 16 per cent. The management does not hesitate to credit the apprentice program largely with this remarkable result. Some service apprentices are now in training at the Lansing plant and it is contemplated that this phase shall be enlarged. John M. Amiss, superintendent of apprentices, has been largely responsible, after a sympathetic and enthusiastic management, for this splendid showing.

SUMMARY

Apprenticeship in the automotive industry is not only a possibility but an actuality. The results have proved the necessity and value of apprenticeship.

One of the greatest future developments in the automotive field will take place in the training of personnel. The effect of a comprehensive and adequate program upon the industry as a whole is certainly more than a matter of speculation.

Apprenticeship for the most neglected field, that of service, rests largely with the impetus of an example set by the manufacturer, in addition to the actual support of such a program.

It is possible to point to outstanding examples of success of personnel training in the automotive field, proving by facts the possibility of a comprehensive application of apprenticeship.

The following results can be expected from an adequate program of training:

(1) A sufficient number of toolmakers, machinists and die-sinkers
(2) The creation of a supply of trained personnel that can be shunted into engineering, drafting, servicing, and supervisory departments and positions as needed
(3) The stabilization of the working force
(4) The reduction of turnover; the saving effected in this manner would be in itself compensation for the cost of training
(5) The formation of the best defense against adverse economic doctrines by the education of the backbone of an organization
(6) The key to unlock the most fertile field in the automobile world, adequate servicing of cars

THE DISCUSSION

R. E. PLIMPTON[2]:—Mr. Frommelt's definition, that apprenticeship

> is merely a method of helping the young man complete his education no matter where he leaves school, be that grade school, high school or college

is one in which I heartily concur; but it seems that the author is interested more in a narrower form of training, in which boys of about the age to enter high school are given a 4-year course including shopwork, a certain amount of teaching and mathematics, sketching and other subjects. This is all very important and necessary. A still more important matter for the members of the Society, since it affects the caliber and development of future members, is the help to be given young men who have completed a formal course in technology and are starting their working life in the automotive industry. These young men can become Enrolled Students of the Society and then receive help in getting positions through its Employment Service. An even larger part of the young engineers entering our industry make direct contacts with the factory or other organizations. The latter may cover the service station or the fleet operator, since both are beginning to open up an attractive field for the young engineer.

In spite of the fact that hundreds of these young men are entering the industry every year equipped with a good engineering education, there seems to be very little attempt to organize their work. Is there not a need in many of the larger plants for a formal course that would take young mechanical-engineering graduates, put them through various departments of the shop, supplement this work by lectures of an appropriate nature and, finally, secure for those who have finished the course permanent positions in accordance with their capabilities? Some of them may go into production work, into research or design, into sales engineering, or into operation and maintenance. A certain amount of this work is already in progress, and I suggest that this activity can be expanded and strengthened by the Society.

TRAINING OF ENLISTED MEN OF THE UNITED STATES ARMY

LIEUT-COL. EDGAR S. STAYER[3]:—In regard to the training of enlisted men of the Army for repairing the vehicles used for so-called motor transportation, about 5 years ago I made an attempt to bring to the attention of the industry the fact that the kind of service being rendered by the automotive industry to the user of an automobile or truck was very unsatisfactory, and that this service could not be rendered satisfactorily until the automotive industry realized that it is necessary for the industry, as it is for the Army, to educate its own service mechanics; that no longer can employers go into the field and pick up mechanics that are able to render service. Mr. Frommelt's paper indicates that, at last, the automotive industry has realized this condition.

One point in Mr. Frommelt's paper must be thoroughly appreciated before any apprenticeship program can be made an unqualified success; it is that "an apprenticeship should be made more of an education than a mere job for the young men engaged upon it." Apprenticeship is fundamentally a method of training used to produce the best possible workman in the shortest possible time. Any factor that increases the time element is detrimental to both the organization and the man. To avoid this, the apprentice should be considered primarily as a student and not as a cheap workman to whom such incidental training is given as is convenient.

In the Quartermaster Corps School, the student is given thorough instruction in the fundamentals of his particular line of work and enough practical work to teach him to apply these principles in practice. Insofar as possible, the practical work is tied in with the production program of the shop. Usually, little difficulty is experienced in such coordination. The technical skill that can only come through long practice is not considered as one of the prime requisites of apprenticeship training. To include this requires a period of training of a length out of all proportion to the benefits derived by either the organization or the man. The student is actually "learning a trade" at all times during his apprenticeship and not merely holding down a job.

With us in the Army service, it is a matter of completing the education of a Quartermaster Corps soldier who has taken up the specialty of transportation. The Quartermaster Corps has established at Camp Holabird the finest training-school for service repairmen of automotive equipment for transportation purposes that exists in this Country and is training mechanics and using their efforts in productive labor in the repair of the transportation units used by the War Department in a man-

[2] M.S.A.E.—Associate editor, *Bus Transportation*, New York City.
[3] Commandant of the Quartermaster Corps Motor-Transport School, Camp Holabird, Baltimore.

ner far in advance of that used in the commercial world in the automotive industry.

The only way in which the Army can expect to maintain its transportation is by sending those soldiers who make transportation a specialty in the Quartermaster Corps to an institution like this, or similar to this, where the training schedule is the same as that being used at this station and will produce the same results as are produced at this station, thereby enabling the War Department to have its own trained service or repair personnel for its own automotive equipment. The fact that the automotive industry has just reached this stage is sufficient for maintaining Camp Holabird and sufficient for the expense that it has been in the past, and the economic measures that are being installed at Camp Holabird at present will enable these good results to be obtained by the War Department and Army at large at a less cost than that of any other installation doing similar work within the limits of the United States.

Courses of Instruction

The regular course of instruction for officers at the Quartermaster Corps Motor-Transport School covers a period of 9 months. It is given for officers of the Regular Army, National Guard, Organized Reserves, and Marine Corps of the United States, as well as for officers of the armies of foreign countries. The course aims to give the student a thorough training in the fundamentals of motor-vehicle maintenance. The objects of the course are to develop managers of motor transportation; instructors competent to supplement the activities of the school in meeting the needs of organization for specially trained personnel; officers trained in the repair and maintenance of motor transportation; officers trained in the management of motor-transport organizations; officers trained in the tactical use of motor transportation; and officers trained as assistants to the General Staff for transportation and as mechanical inspectors and advisers on motor transportation.

The instruction consists of lectures, demonstrations, conferences, problems, and practical work in various departments of the motor-transport shop and in vehicle operation. Sufficient practice in the use of tools and the repair of vehicles and their component parts is given to enable the student to supervise work in the field intelligently. The work also covers such subjects as shop management, unit replacement and traffic control. Before completion of the course, students are taken on a practice convoy that is designed to give them actual experience in vehicle operation on the road.

The course for officers is designed with a view to preparing an officer for the conduct of motor-transport activities, regardless of his assignment, whether it be as commanding officer of motor-repair section, motor-transport company, motor-parts warehouse, or other motor-transport activity. It is not designed to make a specialist of the officer in motor mechanics or repair. It is designed to develop the officer into an efficient administrator; to give him the fundamental principles of motor-transport equipment and sufficient detailed practice in the use of tools, in the repair of vehicles and in their operation that he may carry on his work in the field in an intelligent manner. The course is further designed to include sufficient study in *tactics* and *supply* to enable the officer more fully to *appreciate the duties and functions of officers of the general staff, to know the relation to other arms of the service* and to be able to talk in an intelligent military manner with other officers of the Army.

The regular course of instruction for enlisted men at the Quartermaster Corps Motor-Transport School also covers a period of 9 months. Students are taken from the Regular Army, National Guard, Organized Reserves, and the Marine Corps of the United States. The course is designed to give the student a thorough training in the repair and upkeep of motor-vehicles, such as are used in the Army, and other component parts. The objects of the course are to train enlisted men as instructors, in their respective units, in the theory and practice of operation, maintenance and tactical employment of motor transportation; as instructors in one or more of the special trades connected with the operation and maintenance of motor transportation; and as general foremen in the repair and maintenance of motor-transport establishments.

The regular courses of instruction for enlisted men are designed with a view to giving the training necessary for the soldier to acquire proficiency in the particular line of work with which he will be chiefly concerned upon completion of the course. To take care of the varying needs of the individual students, three options are given: (*a*) the general course, (*b*) the engine-specialist course and (*c*) the ignition and carburetion-specialist course.

The allied-trades courses of instruction for enlisted men are designed to give training in the fundamental principles and their application to one of the trades closely associated with motor transportation. With the exception of the machine-shop course, which occupies the entire school year, each of these courses is repeated three times during the year. Considerable advantage to the student, in added proficiency, will result if the student be allowed additional training in the shops of the School following this course.

Quartermaster Corps Personnel Training

Lieut. Walter C. Thee[4]:—To support Mr. Frommelt's statement that apprenticeship training in the automotive industry is not only a possibility but an actuality, I will cite a few outstanding examples of success of the personnel training experienced by the Quartermaster Corps, United States Army, at its transportation school located at Camp Holabird, Baltimore. The Motor-Transport Branch of the Quartermaster Corps has succeeded in developing toolmakers, machinists and die-makers out of men who enlisted in the service without a trade or profession. Within 3 months after a man has completed his recruit drill and received disciplinary training he can be taught to regrind cylinders and crankshafts; rebuild ignition units, carbureters, magnetos, generators, differentials and steering-gears, and to fit any parts of a motor-vehicle.

Regrinding cylinders is something Mr. Frommelt hesitated about going into detail on; but, recently, I questioned a man in the shop who was working on a grinding machine. In reply, he said he came into the service 6 months previously from the coal fields of Pennsylvania and had been working on that machine 3 months. He was actually regrinding cylinders down to 0.001-in. accuracy which were passing inspection.

The way this training is carried on is by actually working the men in the shops and giving them three lectures a week. The shop is divided into different departments. The foreman of each department who is generally a staff, technical or master sergeant is the instructor. Each department has assigned to it an inspector who is

[4] Quartermaster Corps Motor-Transport School, Camp Holabird, Baltimore.

also an instructor. He informs the student if his work is not accurate or correct. All finished work must pass inspection before the foreman of the department can be given credit for any work on his production schedule.

We have also found that training develops men for higher positions; that is, it qualifies them for staff, technical and master sergeants so that they can hold positions as department foremen, inspectors, instructors, and the like. Training also gives men faith in the service and encourages reenlistments, draws recruits and reduces the number of desertions. Training develops the Army personnel so that it can carry on the work independently without the assistance of civilian specialists. This reduces the cost of operation and the necessity for additional funds that cannot be depended upon, since the appropriations, with our present budget systems, are very difficult to obtain and must be reduced to the absolute minimum. The training of enlisted men to do the work is our only solution and salvation.

To illustrate further the necessity and success of personnel training, it supplies the Army with skilled mechanics and specialists for the field; that is, the outlying stations in the various corps areas. These specialists are developed from raw recruits received from the recruiting stations. We cannot hire our skilled labor because we seldom have sufficient funds. We are compelled to train the men, and this has proved to be the proper thing to do. To hold these men after they have received this training, it is necessary to make the service still more attractive to them. After a man gets a diploma, and after he finishes a certain trade or a certain subject, he can use this diploma when he takes his examination and he will be credited and exempted from examination in that subject. There are various ways to make the service attractive.

Production and training are highly coordinated. The shop executive who is charged with production prepares a production schedule every month. The officer in charge of training has a definite training-schedule prepared which informs each student what he is to do for each hour in the day. The foreman of each department uses the production schedule as much as possible to train these students. If certain fundamental principles are taken up in the lecture room and cannot be applied on orders listed on the production schedule, he uses the equipment in the school laboratory where every type of unit installed on a motor-vehicle is available. In this manner, every student actually applies all the fundamental principles he learns in the lecture room.

The Quartermaster Corps Motor-Transport School is operated in conjunction with the Quartermaster Corps Motor-Transport Reconstruction Park located at Camp Holabird, Baltimore. The latter organization is manned by a motor-repair battalion that averages a personnel of about 500 men and is laid out in department areas so as to give an individuality to each trade or subject and simplify operations and organization. This year, the School enrolled about 90 enlisted men and 8 commissioned officers to receive a 9-month course of instruction in the maintenance and operation of motor transportation. The enlisted men are permitted to choose the subjects that they desire such as welding, blacksmithing, tire repair, trimming and upholstering, painting, woodworking and body repair, machine-shop, ignition and carburetion, internal-combustion engine specializing or the automobile-mechanics' general-course.

The commissioned officers are required to take a special course that has been outlined for them and is intended to train them to be managers of transportation. This includes instruction in and application of the fundamental principles of the various units used on motor-vehicles and in the elements of highway transportation. The latter covers capacities of highways, traffic census, traffic resistance, road circulation, and loading and operation of vehicles for transportation of supplies and personnel.

The shops are divided into various department areas in the following manner:

(1) Reclamation, where unserviceable vehicles and units are dismantled, inspected and cleaned
(2) Machine-Shop, where all unserviceable parts are machined and refitted. This includes regrinding cylinders and crankshafts, and fitting main and connecting-rod bearings of engines with a single-point boring-bar, all scraping of bearings by hand having been discontinued
(3) Engine Assembly, where fitted engine parts are assembled. In this department, is included the dynamometer testing-stand where 10 engines can be "run-in" and tested at the same time
(4) Accessory Units, where ignition systems, carbureters, magnetos, motor generators, starting motors, oil and water-pumps, oil-gages, air-pressure gages, fans and the like are rebuilt
(5) Heavy Units, where fitted parts of rear axles, brakes, differentials, transmissions, universal-joints with propeller-shafts, clutches, steering-gears, front axles and the like are assembled
(6) Storage-Battery, where batteries are rebuilt, and recharged
(7) Sheet Metal and Radiator Repair
(8) Blacksmithing and Welding
(9) Tire Repair
(10) Woodworking and Body Repair
(11) Trimming and Upholstering
(12) Painting
(13) Schedule and Routing
(14) Cost Accounting

As already stated, production and instruction are closely coordinated. The foremen and the inspectors of each department are the instructors. At Camp Holabird, the activities of inspection and training are separated from the duty of production by assigning them to a definite group of officials.

PROF. GILBERT A. YOUNG[5]:—We have found it difficult to place in the automotive industry technical graduates who have spent a part of their 4 years at college in specializing along the lines of automotive engineering. During the last 5 years Purdue University has graduated approximately 110 mechanical engineers per year. Last year, representatives from 96 companies came to Purdue and wanted to employ our graduates in mechanical engineering, but of this number only one automobile company was represented. The interesting fact is that a considerable number of graduates in mechanical engineering gradually work into the automotive industry.

We are studying the relation of the educational institutions to the industries through the Society for the Promotion of Engineering Education. Many men who enter the colleges now do not possess the mathematical type of mind that enables them to make a success as technically trained men. In these 4 years there ought to be a place to which these men can gracefully retire without being made to feel that they have "flunked out" or that they have been thrown out. We feel that if the universities will consider it carefully and if we have the right contacts with the industries, when the time came

[5] M.S.A.E.—Head of school of mechanical engineering, Purdue University, Lafayette, Ind.

for a man to retire, say at the end of his freshman or sophomore years, he should be able to do so without being made to feel that he is a failure. He should be of service to the industries and finally obtain a position where eventually, with training, he would become a valuable man in that industry. If this could be accomplished he would not have lost his ambition. I think it is a great thing to keep the idea of failure out of the experience of any man. I congratulate the industries that they have recognized this possibility of utilizing men, giving them special training, recognizing their possibilities, and placing them in a field in which their talents will be used and developed to the greatest advantage.

PROF. JOHN YOUNGER[6]:—I agree with Mr. Frommelt that apprenticeship is necessary to every man, whether he is to be a millwright, a toolmaker, a pattern-maker, or whether he is to be some kind of an executive. A mistaken idea exists that because a man goes through a classroom or through a college he is fitted to go into industry at once. Even a man who is graduated with a degree must go through an apprenticeship in industry, because the atmosphere in the two places is entirely different. Unfortunately, manufacturers have felt that they should delegate that responsibility to the trade schools and to the universities, but in so doing they shirk their own responsibility. That is very true in the automotive industry. The companies are expecting to get men already trained. They cannot do it. Men have to serve apprenticeship.

I am very glad that the Society is taking up this question of training and apprenticeship. I had my own apprenticeship some years ago and was very fortunate in having had a trainer and a teacher. This man told me two things that I have always found useful. One is to look backward in the job, and the other is to look forward. If a man is only shaping a nut, he should find out where that nut came from and where it is going and what stress the nut will withstand. Thus he projects himself into the engineering field. An unfortunate idea exists that jobs are specialized, but I have never found a job so specialized that the man in it was not benefited by a broad training. The broad training he gets in apprenticeship must be of value to any man who is entering industry.

F. C. SMITH[7]:—Speaking from the standpoint of the trade school, it does not pretend to turn out a finished automobile-mechanic in any sense of the word. We do not even try to develop in him a marketable skill. Our purpose is to give the man the fundamental principles of automotive construction and operation upon which he can become, after employment in the industry, an asset in place of a liability to the employer.

Does Mr. Frommelt believe that young men of the type that the industry is looking for will come into the industry with the 4-year indenture of apprenticeship ahead of them before they become real mechanics? Also, does he believe that, with the intelligent cooperation of industry, the training agencies such as the public schools and the trade schools cannot do this job of training mechanics just as well and more economically than it can be done by an apprentice system within the industry itself?

H. A. FROMMELT:—In answer to the first question, it has been proved from actual experience that young men will come in sufficient numbers into these 3 and 4-year-apprenticeship courses to satisfy the industry. To my mind, no other industry has such outstanding characteristics to entice young men into it as has the automotive industry. The foundry business in this Country has been in sore need of skilled help. Within the last 9 years, very little or no training or apprenticeship was had. At that time we decided to attempt it and it has since been proved that the young American boys 16 years of age and over can be induced to enter the foundry business on a 3 or a 4-year-apprenticeship basis. I am certain that any industrial community having automotive plants as a portion of its industrial make-up can get all the young men to enter the trades who are needed to supply the demand in those automotive plants. I think there can be no question about that, in view of past experience.

With regard to the trade-school program of training for industry, I say that the trade school can do a very good piece of work in bringing the training of the boy up to a certain point before he enters the regular shop in industry. It will act much like the vestibule shop in a plant where the training program is entirely divorced from the production side of the business. I do not agree with the notion that the trade schools can do the job entirely. I have acted on that belief in the last 10 years, actually inducting young men from full-time trade-schools, and feel that it is necessary to put them, after their trade-school program has been finished, on a period of at least a year or two of definite apprenticeship training, depending upon their age and the length of time they were in the trade school, the quality of their work and so on. I am convinced that this training for industry cannot be done solely in a school shop; some portion of the training must take place right in the industry. I know from experience that it has been adopted in some of the larger industrial communities in the Central West and it has utterly failed to supply the mechanics required.

It is impossible to build schools on a sufficiently large scale in sufficient number to make it a physical possibility to do the training entirely in those trade schools. For example, the Milwaukee community started in 1906 with a trade school built and financed solely by the manufacturers in the City of Milwaukee, with the idea that

> here we have a piece of machinery to do this training-work outside of the shops and we are not going to be bothered with it in our regular production work.

They continued with that for 4 or 5 years and found it actually failed to give results. Then they turned it over to the City of Milwaukee and today it is running as a technical high-school. I cannot find a single case of a mechanic in Milwaukee who has graduated from the technical high-school there in a period of 20 years. It is because the people who can send their boys to a full-time school will send them to a full-time high-school and to a college. I have had men come to me and say, "I have finished my trade-school work. Give me a job as foreman." We were able to take them; they constituted splendid material and had excellent training for 3 years. With an additional year or two in the shop we were able to inspire them with the idea that they had splendid opportunities in the plant provided they were willing to absorb these other things that go with an actual shop-atmosphere.

I am convinced that this training proposition should be carried out partly or wholly in the plant. The schools

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[7] M.S.A.E.—National director of the Young Men's Christian Association and technical trade schools, International Council of the Young Men's Christian Association, New York City.

can help to a great extent and we need them. They should be drawn into this educational program in a very vital manner. There is, and should be, no thought of competition between the schools and apprenticeship. The one is supplementary to the other. The schools are vitally essential to apprenticeship.

MR. SMITH:—We expect to start a campaign to analyze this whole situation. We want to examine at least 10,000 mechanics and students throughout the Country. Part of these men have already been examined. In this examination we will try to find out three things about a man who is in school and about a man who is employed. We are giving him an intelligence and a mechanical-aptitude test and we are going to find out what the employer thinks about the man. We will then divide them into two groups, the boys who went to trade school before employment and the boys who served apprenticeships only. When we are through we will be able to judge whether it is better to send a boy to trade school first or better to have him serve an apprenticeship only. What the industry needs is a standard training-program functioning through agencies that already exist and backed by the industry.

CHAIRMAN LOUIS RUTHENBURG[8]:—This apprenticeship situation is decidedly in a state of flux. To accomplish the best results, men trained in different specialized fields must contribute their specialized talents and training. An interesting thing about our rapid industrial advance is that men become highly specialized and that, when one tries to do something new and has to introduce a combination of the elements peculiar to more than one of these specialized fields of thought, it is sometimes difficult to accomplish the result. I refer particularly to the difference in the schools of thought that control education and that control industry as such. We need a combination of those schools of thought. It is a most fortunate thing for industry that men with the academic point of view, soundly trained in pedagogy, are coming into industry and, similarly, that men with the industrial viewpoint trained to think in terms of industrial economics are being inducted into our educational institutions. I believe the time will come very soon when those two schools of thought will be so correlated that they will be made available to all of our industries and particularly to the very progressive automotive industry in which we are engaged. Certain of our industries have been peculiarly fortunate in enlisting the assistance of men who have had a fine blend of experience both academic and industrial. Such men will in time come to be as much a part of our industrial organizations as our works managers, our financial men, our engineers and our sales departments.

[8] M.S.A.E.—General manager, Yellow Sleeve Valve Engine Works, Inc., East Moline, Ill.

PRODUCING OIL BY GAS LIFT

THE theory that oil is moved through the producing formation to the well by the expansive force of a dissolved gas and that in the case of the flowing well this same force is used in lifting the fluid from the lower portion of the well to the surface is generally accepted by men familiar with oil production. At a comparatively early time in the life of an ordinary well, the volume of gas in the formation declines to a point where it does not exert sufficient force to lift the fluid to the surface, and some mechanical means must therefore be employed. If, in the flowing life of the well, the volume of gas becomes excessive and this excess gas be retained in the formation, it can later be used for moving and lifting additional oil, with a greater ultimate yield per well. Laboratory tests on a particular oil show that 344 cu. ft. of gas can be dissolved in 1 bbl. of oil at 1800 lb. per sq. in. Under ordinary flowing conditions for this particular type of oil in its particular field, approximately 2400 cu. ft. gas was produced per barrel of oil at 1800-lb. rock pressure, which is over six times the volume of gas dissolved in 1 bbl. of oil. Therefore, it follows that for each barrel of oil lifted by this method 5 bbl. of oil was left in the formation which was robbed of the activating force of this gas. This resulted in 5 bbl. of "dead" oil remaining in the formation which, theoretically, could not be recovered by ordinary pumping methods. Decreasing the gas-oil ratio increases the ultimate recovery of oil, and, therefore, this ratio becomes an index of the efficiency of recovery. Under the same pressure conditions, the closer the gas-oil ratio approaches the gas solubility factor, the closer the ideal production conditions are obtained for 100-per cent recovery, giving due consideration, however, to the possibility that encroachment of edge water effects a possible natural water drive which might reclaim some of the "dead" oil.

Using the gas-oil ratio data for pumping and gas-lift wells during the last year in Southern California, a direct comparison showing the estimated percentage recovery by these methods and also the expected increase of recoverable oil from the original oil in the formation that would not have been recovered by the pumping method is afforded. On the basis of this comparison, 23 per cent of the total oil in the sands was found to be recoverable by the pumping method and 33 per cent by the gas-lift method, a net gain of 10 per cent of the total recoverable quantity of oil, or an increase of 43 per cent over the original calculated ultimate production of the pumping well. An analysis of these data suggests that by the use of the gas lift we have accomplished two prime purposes; first a saving in the number of cubic feet of gas per barrel of oil lifted and second, a conservation of gas in the sand to help activate the oil remaining in the formation.

In addition to the application of these principles to the area in which we have ordinary flowing and pumping problems, in at least three cases wells that were ready for abandonment because of the fact that their mechanical condition made it impossible for them to produce by pumping methods without the necessity of spending an amount of money that would make it a non-commercial venture were salvaged. The three cases cited indicate a practical conservation of the quantity of oil recovered by the use of gas lift in that it was found possible to introduce small tubing in these wells and flow them by this method with the result that over a 4-months period these wells produced 21,000 bbl. of oil.

An important question concerning the gas-lift process is one having to do with the quality of the oil produced by such methods as compared to the quality of the oil from the same well as produced by the ordinary methods of flowing and pumping. As a result of the data available comparative samples taken before and after gas lift show nine wells with oil gravity lower and nine with gravity higher, after the introduction of the gas lift, the average of all showing 0.23 American Petroleum Institute deg. higher after the introduction of the gas lift. This indicates that the quality of the oil produced and run from the field tanks under the gas-lift method of production is at least as good as it was under the pumping system. Under certain conditions an excess stripping of the oil by the gas undoubtedly results. One test indicated a reduction in the gravity of the oil of 1.3 American Petroleum Institute deg. and a reduction of 4 per cent in the 54-per cent gravity gasoline content, which, however, was recovered in the subsequent treatment of the gas in the absorption plant.—C. R. McCollom, before American Petroleum Institute.

Motorcoach Maintenance Methods

By Henry L. Debbink[1]

Milwaukee Section Paper

ABSTRACT

A FLEET of 141 motorcoaches operated by the Milwaukee Electric Railway & Light Co. travels an aggregate of 400,000 miles per month, or four times the total monthly mileage of the company's fleet of 175 automobiles and trucks. New maintenance problems have developed. Periodic inspections are required four or five times as often.

Road-delays have made many changes in maintenance methods necessary, especially after a period of service. A list of the more common types of failure in the early equipment is given.

The author describes progressive changes in the inspection and overhaul system that finally developed into the present system of regular inspections at intervals of 1000 miles of operation, which include inspection of the parts that give most frequent trouble, draining of the crankcase oil, and greasing of the chassis; a general and more thorough inspection after each 4000 miles; and a general overhaul of the chassis and body at intervals that average 30,000 miles.

The 1000-mile inspection is made between runs or at night and does not interfere with the regular operation of the motorcoaches. With the special facilities that are provided, it can be made by a mechanic and a helper in 45 min. A list of the inspection and lubrication work to be done at this inspection is given. An unusual item is the draining of a sample from the gasoline main-tank and noting if any water is present. This is done to make sure that no water from condensation has collected that may freeze in the gasoline-line to the engine.

The general chassis overhauls require from 3 to 6 days and the body overhauls and painting from 5 to 7 days. The body is not removed from the chassis unless frame repairs are needed, and the chassis and assemblies are not torn down. If standards of wear that are set are exceeded, the units are removed and replaced by overhauled assemblies. The author tells what routine work is done on the chassis. In general, the four cylinder engines are changed at every alternate overhaul, or after about 60,000 miles of operation. The newer six-cylinder engines probably will be changed at every third or, in some cases, every fourth overhaul.

Special facilities that save time and labor are an inspection pit with two floor-levels for working on chassis, a grease pressure-line in the pit with a convenient nozzle for forcing grease into the Alemite fittings, a funnel also in the pit into which crankcase oil is drained to an underground tank whence it is pumped to an oil reclaimer, spray washing-racks that enable washers to accomplish over four times as much as washers did previously without them, and a floor-type dynamometer with which the coaches are given a road-test without leaving the garage and overhauled engines that have not been removed from the chassis are run-in.

Storage facilities for 1,000,000 gal. of gasoline are provided and gasoline is bought in tank-car quantities when prices are low. The company uses 30,000 gal. of lubricating-oil per year.

Discussion of the paper is comprised mostly of questions and answers relating chiefly to the company's experience with steam-cooling and steam-heating, with reclaimed oil, with different types of brake, with oil-filters, the fields for four-cylinder and six-cylinder engines in motorcoach service, the apparent trend of some operating companies to build their own vehicles, a comparison of the operating economies of gasoline motorcoaches and electric street-cars, and the attitude of the author's company toward use of the gas-electric motorcoach.

MOTORCOACHES have been operated in city and interurban service since the summer of 1919, and automobiles and trucks for a considerably longer period, by the Milwaukee Electric Railway & Light Co. The fleet has grown steadily and now includes a total of 175 automobiles and trucks, which are operated an aggregate of about 100,000 miles per month, and 141 motorcoaches, which make close to 400,000 miles per month.

It will be noted that the motorcoach fleet, embracing a smaller number of vehicles, makes four times the mileage of the general-service fleet. This high mileage is responsible for the fact that motorcoach maintenance has presented problems that are different from those we had before. Not only are periodic inspections required four or five times as often, but the total mileage a vehicle makes before retirement is four or five times as great as that made by an automobile or a truck, and maintenance operations that are rare on trucks must be performed regularly on motorcoaches. In addition, the high mileage that coaches make exposes weak points of construction that the builder did not suspect.

In the motorcoach it was necessary to combine with the ability of the motor-truck to perform satisfactorily under continuous heavy loading, some of the superior appearance, riding-qualities and quietness of operation of the private automobile. It is of greatest importance, however, that the motorcoach be able to run from 40,000 to 60,000 miles per year for 4 or 5 years at a reasonable cost. It is not strange, therefore, that motorcoach maintenance-troubles are numerous. To so combat these troubles as to eliminate as many road delays as possible and still keep costs within reason it has been necessary to make many changes in maintenance methods from time to time.

Fleet Growth Required Larger Garage

Growth of our motorcoach fleet was slow during the years 1919, 1920 and 1921. At first we made such current repairs as were shown to be necessary, usually by the failure of some part, and when a major failure occurred and a vehicle was in bad general condition it was given an overhauling. In 1920 a system of weekly inspections was started. This meant inspection of the motorcoaches after running from 700 to 1000 miles, the average weekly mileage, and the inspection included changing the crankcase oil, lubricating all parts, and making necessary mechanical adjustments and repairs. This system was followed until July, 1922, when the rapid growth of the fleet was overtaxing the capacity of the company's garage and made it necessary to transfer all of the motorcoaches to the new Kinnickinnic garage.

Simultaneously with the removal the maintenance operations were changed to a mileage basis upon which the

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vehicles were given a complete inspection after every 2000 miles and an annual complete overhauling and painting. The only work done between inspections was that which was necessary to correct troubles reported by the drivers. The mechanics in the inspection crew were divided into groups and trained as specialists to work in the following departments: engine and oil efficiency; electrical system and gasoline efficiency; clutch, gear-set, steering-mechanism, front wheels and front axle; rear axle and brakes; and body and signs.

This 2000-mile inspection-system worked satisfactorily while the motorcoaches were fairly new but when they had made from 20,000 to 30,000 miles serious equipment failures increased rapidly in number. These were due partly to (*a*) the fact that some of the early buses were developments of truck design and did not have the necessary differences in design required for a coach with long wheel-base, different wheel construction, and heavy service on the brake and clutch, and (*b*) to the fact that some were developed for city service and the needs of interurban service, in which continuous high speeds are necessary, were not fully appreciated.

Equipment Failures That Assumed Importance

Some of the equipment failures that began to assume importance after the vehicles had made a little mileage are as follows:

(1) Disc-wheel failures, before special attention was given to maintenance of the wheels
(2) Propeller-shaft-disc failures due to too small capacity of the discs
(3) Scored cylinders and sleeves due to improper wrist-pin locking devices
(4) Cracked cylinder-blocks due to incorrect design and lack of sufficient thickness of the castings
(5) Broken flywheel bolts, before oversize bolts were installed
(6) Broken axle-shafts and wheel bearings because the strains due to the use of dual pneumatic tires were not appreciated fully
(7) Frequent radiator failures on certain types of motorcoach due to too light construction
(8) Broken frames
(9) Worm-gear and worm-bearing failures due to use of an inverted worm without sufficient provision against leakage of grease
(10) Breakages of differential bolt due to improper material and locking devices
(11) Propeller-shaft center-bearing failures

As each of these classes of failure presented itself, more and more work was done on the vehicles at the time of the 2000-mile inspection, to prevent failures on the road from these causes as far as possible. For example, when axle-shaft and bearing failures on one type of motorcoach became very frequent, we started the practice of removing the wheels, hubs and shafts at every inspection to examine properly the bearing, bearing retainer, and fit of the hub and shaft. This required from 5 to 6 hr. of labor. Previously we had merely jacked-up the axle, tested the bearing for play, tightened the nut that holds the hub on the shaft, and did not remove the hub and shaft assembly except when the bearing showed excessive play. Ordinarily this would take from 12 to 30 min. In such ways the thoroughness of the inspection was increased in an endeavor to eliminate failures on the road from other causes of trouble, but as more and more work was added to the inspection schedules they began to resemble annual overhauls. They involved so much labor that it was impossible to make them on the 2000-mile basis unless an excessively large garage force was employed and a large number of motorcoaches were kept out of service every day for inspection.

Trial of Regular and Special Inspections

It was impossible to continue in this way indefinitely and in 1923 it was decided to try doing this extra work at less frequent intervals. We then started a system of giving the vehicles a 2000-mile regular inspection and a 10,000-mile special inspection. At the special inspections we ground the valves and cleaned the carbon from poppet-valve engines, removed the junk heads and cleaned the carbon from sleeve-valve engines, removed the engine-pan and examined the connecting-rod and main bearings, removed all wheels and hubs and examined the bearings, dropped the propeller-shaft to examine wear and play of the worm, and made the whole inspection more thorough than at the regular inspections.

This system was followed for 4 months to give it a thorough trial. The trouble with it was that for various reasons, such as road conditions, much of this special work might frequently be necessary before a motorcoach had made 10,000 miles after the last special inspection. When such work became necessary the next inspection was made a special one. The types of failure increased in number as the coaches made higher mileage, and soon a large percentage of the regular inspections had to be made specials. This involved an increase in work and therefore an increase in mileage between all inspections. Consequently, a system which in effect was a method that we had actually been forced to follow for some time was tried; that is, the practice of giving the motorcoaches regular inspections on a 4000-mile basis and including in each inspection such special items of work as examination showed to be necessary. The records of delays on the road showed that the coaches could be operated an average of 4000 miles between inspections and still give good road performance if the inspections were thorough. Inspections at this interval do not, however, provide lubrication often enough, therefore we lubricated between inspections. For convenience in following a schedule, instead of lubricating on a mileage basis, we greased all the motorcoaches one week and changed oil in all of them the following week. This meant that every coach was greased and the oil in it changed on an average of a little less than 2000 miles.

Inspections and Overhauls on a Mileage Basis

This system developed gradually into the present system under which the oil is drained, the chassis is greased, and those parts which give most frequent trouble are inspected after every 1000 miles, and each motorcoach is given a general inspection after every 4000 miles. The 1000-mile inspection does not interfere with operation, as it is given between runs or at night. With the equipment that is provided it can be completed by a mechanic and a helper in 45 min. The work done at this inspection is as follows:

Inspection

(1) Check battery for water and hold-down clamps
(2) Check tire condition and pressures
(3) Set tappets to 0.008 in. when hot
(4) Check length of generator brushes
(5) Clean all spark-plugs and reset electrodes
(6) Drain and clean gasoline-filter
(7) Drain a sample of gasoline from main tank. Is water present?
(8) Adjust brakes
(9) Inspect condition of fan-belt and check fan pulleys for alignment

(10) Inspect fabric universal-joints for loose or missing bolts

LUBRICATION

(1) Drain oil
(2) Fill all Alemite fittings with cup grease
(3) Fill universal-joints and center propeller-shaft bearings with grease
(4) Fill water-pump glands with special grease
(5) Lubricate fan bearings with oil when necessary
(6) Oil throttle and spark mechanism when necessary
(7) Check differential oil-level
(8) Refill crankcase
(9) Check transmission oil-level

Item (7) under "Inspection" is a cold-weather precaution. Some condensation of moisture occurs in all gasoline tanks. Considerably more occurs in the large tanks in motorcoaches, which are located at the rear end in most cases and have a long fuel-line running to the engine and which is not warmed by heat from the engine as a rule. The water of condensation settles and sometimes in below-zero weather the water will freeze in the line and cause the car to stall. Then, if the driver does not act promptly, the engine will freeze. The practice of checking for water in the main gasoline tank is followed for these reasons.

General overhauls of the chassis and body are made at intervals that average 30,000 miles. The chassis overhaul requires from 3 to 6 days and the body overhaul and painting from 5 to 7 days. The body is not removed from the chassis unless repairs to the frame are necessary, nor are the entire chassis and all assemblies torn down.

An attempt is made to establish certain standards of wear. If wear of a part or an assembly exceeds the standard set, the unit is removed and an overhauled unit installed in its place; for instance, if the cylinders of an engine show more than 0.004-in. taper and 0.003 to 0.004 in. out-of-round, or the crankshaft is more than 0.002 in. out-of-round, the engine is changed. Otherwise, valves are ground, new piston-rings installed, new wrist-pins put in if necessary, and bearings taken up. In general, the four-cylinder engines are changed at every alternate overhaul, or after the 50,000 to 60,000 miles of operation. The larger and newer six-cylinder engines give longer service and the indications are that they will be changed only at every third or, in some cases, every fourth overhaul.

The transmission, clutch and steering-gear are cleaned and examined for wear or play and, if necessary, changed. The front axle, together with the springs, is removed and the springs rebushed, cleaned and packed with graphite grease. The rear axle, with its springs, is removed and the springs serviced. The rear-axle center-piece is cleaned, examined, and the necessary work done on it. Our entire attempt is to give the motorcoach a thorough examination and to overhaul those parts that need repairing or replacing but not to tear down and rebuild the vehicle.

SPECIAL FACILITIES THAT EXPEDITE WORK

The company has some special facilities that are of interest. Among these is the 1000-mile-inspection pit. This has a floor with two levels to make it easy to work on chassis of different heights. A grease pressure-line runs along the side so that the man doing the greasing has only to apply a convenient nozzle to the Alemite fittings and grease flows as long as he presses a trigger. Crankcase oil is drained directly into a funnel arrangement, from which it flows by gravity to an underground tank. It is drawn from this tank into the oil reclaimer by an electric pump on the reclaimer. The dirty oil is not actually handled at any time.

Another distinctive facility is the spray washing-rack. When each motorcoach comes in from a run it is first tanked and then washed in this rack. A crew of four washers washes three times as many coaches per day on these racks as six washers did previously without them. The busy times are between 6:00 and 7:00 and 10:30 and 11:30 p.m. A washer stands on either side of the rack and the coach operator stays on his seat as the motorcoach runs up on the washing rack. Each washer washes his side of the vehicle in from 1 to 1½ min. The driver then runs the coach off of the rack and parks it in the garage. Later, when most of the washing is finished, the washers go around and polish the windows with chamois and do interior cleaning. No attempt is made to polish the entire body. Only one washer is on duty on a rack during the daytime, and then the driver does not stay with the motorcoach but leaves it on the rack. Washing the coach, polishing the windows and cleaning the inside take the one washer alone about 15 min.

A piece of equipment that is used in some factories but not in any other maintenance garages is our floor-type dynamometer. This was designed to use two General Electric No. 70 motors, each having a commercial rating of 40 hp., that were removed from old street-cars. With this dynamometer we can give motorcoaches a road-test without their leaving the garage and can run-in an overhauled engine that has not been removed from the coach.

The methods of handling oil and gasoline are modern but not novel. We use more than 30,000 gal. of lubricating-oil and 800,000 gal. of gasoline per year. The gasoline is bought in tank-car quantities. We have storage facilities for almost 1,000,000 gal. so that gasoline can be bought when prices are low and stored for use when they are high. The company's total investment in motorcoach rolling-stock, garage and equipment is $1,670,000.

Many other details of maintenance methods could be touched on, such as the method of handling trouble calls or of branding tires and keeping tire records, but they are omitted to avoid making this paper too long.

THE DISCUSSION

FRED M. YOUNG[2]:—Have you or has your company made any attempt to standardize on any definite type of motorcoach or types of unit, as engines, axles, or transmissions? And has any leverage been used on the manufacturers of motorcoaches to build units that the company thinks are right, or do you accept the vehicle as a whole?

HENRY L. DEBBINK:—We have tried to standardize but we have a variety of vehicles. About the time we think we are settled upon a certain type of coach some company brings out a vehicle that we cannot refuse to use, and to keep abreast of the times we buy that type.

JOHN H. LUCAS[3]:—Progress in the art has been very rapid and great.

MR. YOUNG:—Do you think standardization will come, now that we have arrived at a stage of development when we can, in a greater measure, accept a motorcoach as designed and built?

MR. DEBBINK:—Certain types of body are fairly

[2] M.S.A.E.—Vice-president and general manager, Racine Radiator Co., Racine, Wis.

[3] M.S.A.E.—Superintendent of rolling stock, Milwaukee Electric Railway & Light Co., Milwaukee.

standardized now. When we started to operate interurban service we used the street-car type.

MR. YOUNG:—I had in mind the chassis in particular.

MR. DEBBINK:—Most of our recent purchases have been Yellow and Fageol coaches.

MR. YOUNG:—I have noticed that the Northern Ohio Electric Co. and the Northeastern Transportation Co. have started to build their own chassis to suit their particular conditions. Is that trend due to the failure of the motorcoach builders to understand the operating conditions or are the railway companies so prejudiced in favor of certain features that they want to design their own vehicles?

MR. DEBBINK:—I do not think we shall attempt to do so. Some years ago we built two trucks and they were expensive to maintain.

OPERATORS CANNOT BUILD IN COMPETITION

MR. LUCAS:—They were also expensive to build. We do a great deal of manufacturing of repair parts, not only for maintaining the rolling-stock but for other departments of the company. We are forced into some of this work because the suppliers do not keep adequate stocks on hand and delay us when we need parts for repairs. But we cannot compete in building such a complicated vehicle as a motorcoach, a private car or a street-car. This applies more definitely to motorcoaches and private automobiles because these are built in quantity production. I do not think anybody can compete in the construction of a few special motorcoaches with the big manufacturers who build them by several hundreds or thousands. It is our feeling that it will be a long time before we will endeavor to build to meet our own requirements. These will not be for more than 10 or 12 motorcoaches a year, and it is not worth our while to go into the building of that small number. Moreover, I think the motorcoach makers gain experience from operations in various parts of the Country that leads them to make improvements a little more rapidly than we would do. When we find in our service that certain parts do not stand up to the work, we urge the builder to improve them. All the makers are backward on such things as adequate heating-systems, and we have done a good deal of pioneer work in that respect.

EXPERIENCE WITH STEAM-COOLING AND HEATING

E. A. COUSINS[4]:—Has the Milwaukee Electric Railway & Light Co. had any experience with the steam-cooling system?

MR. DEBBINK:—We have two motorcoaches equipped with steam-cooling-and-heating systems. One is double-decked and has a steam-cooling system with steam-heating on the upper deck. So far as I know this is the only double-deck motorcoach in the Country that has the upper deck heated. The other is a Fageol six-cylinder coach with a steam cooling-and-heating system that looks a little crude in some respects but works satisfactorily.

MR. YOUNG:—Were these operated with steam-cooling all summer?

MR. DEBBINK:—No, but there is no reason that they should not be. Little difficulties kept arising last spring when the weather became hot and, as we could not take the vehicles out of service to do experimenting, we put back the water-cooling system for the summer and returned to steam-cooling for the winter. I think we shall run through next summer with the steam-cooling.

MR. COUSINS:—Are they pressure or atmospheric systems?

MR. DEBBINK:—They have pressure-valves to regulate the steam in the heating system. That is all we try to do and we run up to only a few pounds of pressure.

MR. COUSINS:—I heard recently of one that was put on a motorcoach and operated at 15-lb. pressure. It seems to me that is running the engine at a high temperature.

MR. DEBBINK:—It is. We have had ours running up to 10 lb. although the valve was set for a lower pressure. The gage was not very accurate; it was merely an oil-gage connected in the system.

CHAIRMAN W. S. NATHAN[5]:—What success have you had with the system so far?

STEAM-HEATING THE MOST SATISFACTORY SYSTEM

MR. DEBBINK:—So far as the heating is concerned, it is the most satisfactory system. The exhaust heating-system has many objectionable features. It is necessary to have a large pipe and it is difficult to secure proper distribution of the heat. Very good guards are required to prevent passengers from burning their rubbers or the sides of their shoes, or, if the skirt of an overcoat gets down behind the heating pipe, it is burned. To heat the coach sufficiently it is necessary to have such a high temperature at the front end that great precaution must be taken to prevent charring of the wood around the pipe. The temperature of steam heat is about 212 deg. fahr., which is a very good temperature as regards insulation. The small pipes that extend into the coach do not take up much room; the heater-guards do not obstruct the passage and do not occupy much space, and one has only a little steam-valve to turn on and off, not the conventional heater-valve which often becomes clogged with carbon and gives trouble.

So far as cooling is concerned, the system has proved satisfactory, but we have not been able to show very large savings in gasoline consumption, which we expected to do. I think the reason for this is that the motorcoach engine runs at a higher temperature than the truck or passenger-car engine, hence the difference in temperature between the water-cooled and steam-cooled engines is not great.

MR. COUSINS:—I have an experimental atmospheric steam-cooling system on my Dodge car and obtain a 20-per cent increase in gasoline mileage, but I can see your point.

CHAIRMAN NATHAN:—Mr. Debbink, what difficulties did you have with this system that precluded its use last summer?

MR. DEBBINK:—A rather loud carbon-ping developed. The engines were not really overheated very much but began to be noisy.

MR. COUSINS:—Was it necessary to use heavier oil?

MR. DEBBINK:—No.

DEWITT CLAUSEN[6]:—Does the steam-cooling system provide sufficient heat in cold weather for heating purposes?

MR. DEBBINK:—Plenty of heat is available; the only requirement is to put in enough radiators. In the Fageol parlor-car that is equipped with the steam-heating system two different types of radiator are used. First we put in 6, I think, and then increased the number to 10. This is the warmest motorcoach we have. If it were not warm enough we could put a radiator under each seat, which would give all the heat wanted.

[4] A.S.A.E.—Sales engineer, Hyatt Roller Bearing Co., Detroit.

[5] Jun. S.A.E.—Service department, Nash Motors Co., Kenosha, Wis.

[6] Jun. S.A.E.—Machine designer, A. O. Smith Corporation, Milwaukee.

MR. CLAUSEN:—Would putting all the steam in the heating system bring the temperature of the engine too low?

MR. DEBBINK:—No, ample steam is generated to heat the chassis radiators. The fact that they become hot shows that an excess of steam is going to the water-cooling radiator or steam-condenser. The only time we had any trouble due to all of the steam going to the heating system occurred last winter with the double-deck coach. The operator was a little late for his run and did not wait the usual time to warm-up the engine and look over the equipment. He started on his run with the engine rather cool and all the steam went into the heating system because the pressure-valves prevented it from going to the condenser, and the water in the condenser froze. The fact that this happened only once indicates that the condenser is receiving steam all the time, as we do nothing else to prevent freezing.

SIX-CYLINDER ENGINES PREFERRED

ARTHUR C. WOLLENSAK[7]:—Have you found a field in your service for both the four-cylinder and the six-cylinder engine?

MR. DEBBINK:—We found a field for the six-cylinder engine as soon as a good one was developed, and I am sure the company will never buy any more four-cylinder engines for motorcoach service.

MR. COUSINS:—Can you tell something about the relative maintenance cost of the poppet and sleeve-valve engines on a per-mile basis?

MR. DEBBINK:—So much development in engines has been made that it is hard to compare types, but we can compare two engines that were developed about the same time. Of a number of Fifth Avenue Coach Co.'s motorcoaches operated by our company the engines of the first 10 Model-J single-deck coaches had a 2⅛-in. crankshaft and about 24 of the last four-cylinder engines have a 3-in. crankshaft. We had to regrind the 2⅛-in. crankshafts and refit bearings at every overhauling, that is, after 30,000 miles. With the 3-in. crankshaft many of the engines have run considerably more than 100,000 miles and not a crankshaft has needed regrinding. This shows what a tremendous difference in service a small difference in size makes. The new six-cylinder engines have not been run for a period that necessitates crankshaft regrinding or much bearing replacement.

HOW RECLAIMED CRANKCASE OIL IS USED

A MEMBER:—What has been your experience with oil-filters?

MR. DEBBINK:—We have not bought any oil-filters but have been glad to have them on new equipment where they did not add to the cost. The first we had were on some Fageol coaches with six-cylinder engines. We watched them carefully for awhile after the first five coaches went into service, as we did not know how long the engines should be run between oil-changes. Our regular oil-change period is after every 1000 miles. The floor foreman was instructed to inspect the oil when it was drained out and, if it had good body and fairly good color, to have it put back again, but if it was kerosenish and was black to discard it. A sample from every one of the first 40 drainings was sent to the laboratory and in almost every case the analysis confirmed the foreman's judgment formed from rubbing the oil between his fingers. We found in many instances that the oil had good body after 8000 miles, whereas in some cases it had to be changed after 2000 or 3000 miles. To be on the safe side, and as we have an oil reclaimer, the oil from every engine that has an oil-filter is changed after 2000 miles and from every other engine it is changed after 1000 miles.

[7] M.S.A.E.—Chief engineer, Sterling Motor Truck Co., Milwaukee.

MR. COUSINS:—How is the reclaimed oil used?

MR. DEBBINK:—It is mixed with new oil.

MR. COUSINS:—In any definite proportion?

MR. DEBBINK:—Three grades of oil are used in the engines; one in all poppet-valve engines, a heavier grade in all sleeve-valve engines, and a still heavier grade in the Fageol or Hall-Scott engines. All three oils are from the same manufacturer and of the same general nature. To simplify the work of oil-draining, all three grades of crankcase oil are drained into one tank. They are then reclaimed and brought up to the specifications of the medium-heavy oil. This is then mixed 50-50 with new middle-grade oil and with one-third to two-thirds of the new lighter grade of oil.

MR. COUSINS:—Are you satisfied with the reclaimed oil?

MR. DEBBINK:—Yes.

MR. LUCAS:—The laboratory tests show that it has exactly the same characteristics as the new oil so far as viscosity is concerned.

MR. COUSINS:—At the American Electric Railway Association meeting in Cleveland I talked about oil reclaimers with a man who believed that the reclaimed oil is better.

MR. LUCAS:—It has a darker color.

CHAIRMAN NATHAN:—If I remember correctly, when oil reclaiming was introduced Army aviators said they preferred the reclaimed oil.

MR. LUCAS:—We have used reclaimed oil for a long time in our motorcoaches and street-cars and there is no question that, if properly treated and handled, especially by centrifugal separation which brings it back to exactly the gravity desired, it is fully as good as new oil.

MR. YOUNG:—When you say "treated" do you mean adding something?

MR. LUCAS:—No, I mean cleaned, that is all; taking out all the water and foreign matter. The oil is unchanged so far as chemical characteristics are concerned.

FAILURES CLASSIFIED BY UNITS AND COMPARED

CHAIRMAN NATHAN:—I should like to know about some of the weak points that develop in this equipment. I think that is always of interest to anybody who is manufacturing anything. Can you see much improvement in the more recent equipment?

MR. DEBBINK:—Yes, the improvement in the last few years has been remarkable.

MR. LUCAS:—It would be of interest to explain how we can follow the failures by items and summarize them to learn the trend.

MR. DEBBINK:—A record is kept of all trouble calls each month, of all motorcoach changes, and of all delays of 5 min. or more. These delays are noted carefully and classified according to engine, electrical system, cooling system, clutch, gear-set, rear-axle, tires, traffic conditions, and various other causes. They are then compared with the record for the previous month and for the same month the year before, and when a large number of road delays occur, the causes are given especial attention.

In regard to the weak points, I am uncertain. Every few weeks we become exercised over some particular failure and remedy the trouble and forget it.

MR. LUCAS:—That is, we make a change that corrects the difficulty, but it is my impression that electrical

systems, perhaps, are giving as much trouble as anything.

MR. DEBBINK:—The loads on the motorcoach electrical system are much heavier than the loads on the system on passenger-cars, even relatively. The generators, batteries, and, in almost all vehicles, the voltage regulators, are large, yet a great deal of attention must be given to the electrical equipment.

MR. LUCAS:—Part of the need for attention is due to the use of automobile-size parts instead of larger parts suitable for motorcoach service.

EXPERIENCE WITH VARIOUS TYPES OF BRAKE

MR. WOLLENSAK:—What type of brake equipment has been found most satisfactory? Have you had experience with air-brakes and other power-brakes?

MR. DEBBINK:—We have not standardized on any power-brake but have a number of experimental sets; for instance, an Excelsior vacuum brake on a Fageol. It is not a booster brake and it has two diaphragms and brake levers. We also have several sets of Yellow Coach air-pressure four-wheel brakes, a set of Christensen four-wheel brakes, and a number of sets of Westinghouse rear-wheel air-brakes. We have some metal-to-metal brakes that are air operated, and some that are manually operated.

MR. YOUNG:—What make are the brakes in the Yellow coaches?

MR. DEBBINK:—They are the company's own make.

MR. COUSINS:—Have you ever used any booster brakes?

MR. DEBBINK:—No, that is one of the few types we have not used.

MR. CLAUSEN:—What results are obtained with the air-brakes?

MR. DEBBINK:—They make stopping easier for the operator.

MR. YOUNG:—Do they require an engine with more power?

MR. DEBBINK:—Not noticeably.

MR. CLAUSEN:—I have observed that the stops with air-brakes are jerky.

MR. DEBBINK:—The action depends upon the operator. When we first used metal-to-metal brakes that were operated manually the stops were jerky until the drivers became used to them. They could make a very quick stop but would have a backward rock because they did not release the pressure gradually at the finish. The same thing applies with the air-brakes, but the operator soon becomes used to operating them properly.

MR. COUSINS:—Have you controlled all of them by pedal, or have you used hand control?

MR. DEBBINK:—Ours are all pedal brakes.

MR. COUSINS:—That seems to be the trend.

CHAIRMAN NATHAN:—What does your experience seem to indicate as to the most satisfactory type of brake as regards rear-wheel operation or four-wheel operation?

MR. DEBBINK:—When a motorcoach is designed for four-wheel brakes I think that is desirable, because the stopping ability is limited many times by traction rather than by the braking power; the more brakes the better.

MR. COUSINS:—Do you feel that the four-wheel brake is more desirable for motorcoach service?

MR. DEBBINK:—Yes.

MOTORCOACH AND STREET-CAR COMPARED

CHAIRMAN NATHAN:—We have an unusual opportunity here of obtaining a comparison of the economies of operation of the gasoline motorcoach and the electric street-car. I assume you have made such comparisons, Mr. Lucas. Are they available to us?

MR. LUCAS:—A motorcoach is of smaller unit capacity than the street-car and therefore the cost per passenger carried is higher. I cannot give any exact figures now but in motorcoach operation we think ourselves fortunate if we pay fixed charges on the capital invested. The situation may improve; some lines pay well, with earnings of about 40 cents per mile return profit, but we also have to give considerable service on lines where the earnings are as low as 15 and 18 cents a mile and do not begin to pay the cost of the service.

In making direct comparisons we should have to include all items, such as maintenance of track, powerplant facilities, and things of that kind which are not direct expense on the motorcoach, nevertheless I think that everyone is agreed that for mass transportation we shall have to rely on the street-car system, which performs a service that the motorcoach cannot give. The capacity of the vehicle is the limiting factor. In place of the street-car, in which passengers stand and which carries as many as 150, three motorcoaches would have to be used to carry the same number. Where we now give a rush-hour service with about 700 street-cars about 2100 motorcoaches would be required to perform the same service. If our streets are crowded now, imagine the congestion with three times the number of public vehicles on them. This is as near as I can come to answering your question at present; some other time it may be possible to present actual figures.

A MEMBER:—Has any thought been given to the employment of gas-electric motorcoaches?

MR. DEBBINK:—Every operating company has given some thought to that but the weight of the gas-electric vehicle and the additional expense incurred in putting in that form of transmission seem to us to be too great for the benefits received. With the larger six-cylinder engine the objections to the customary gear-set are not great, and I think we probably shall have still larger engines and undoubtedly improvement in mechanical transmissions that will make the solution much more simple than changing to the gas-electric transmission.

MR. COUSINS:—Have you used any gas-electric vehicles?

MR. DEBBINK:—We tried one in Milwaukee for a few days.

Stresses in Weave-Resisting Frames

By BENJAMIN LIEBOWITZ[1] *Illustrated with* DRAWINGS

ABSTRACT

A MATHEMATICAL analysis is made of the weaving stresses in an automobile frame. These forces consist principally of a twisting couple, the axis of which is the longitudinal axis of the frame. The weave resistance of frames can be greatly increased by the use of torsionally stiff cross-members, or by other means; and the present analysis is confined to the case in which the weave resistance is obtained by the use of such cross-members alone, neglecting any assistance that the frame members may receive from the body or other parts. A frame structure of the simplest form, namely, one having straight parallel side-rails of uniform cross-section, is selected for analysis. The most important weaving-stresses are said to occur generally at or near the widest part of the frame, where the depth of the section is also at or near the maximum; and the appropriate depth and width of an equivalent frame for making the stress determinations is found by trial calculations. The case of the tapered frame is handled similarly to that of a parallel frame by first taking the part of the force at the front or narrow end that is equal to the force at the wide end, determining the stresses in the same manner as for the parallel-side frame and adding algebraically the residual forces acting at the front end, which also include shearing stresses in the cross-members.

WHEN the distribution of load among the points of support of a vehicle frame is altered from that of normal static equilibrium, a system of forces is induced that consists principally of a twisting couple, the axis of which is the longitudinal axis of the frame.

Frames of ordinary construction, such as channel side-rails and channel cross-members, of themselves have relatively low resistance to such couples; their weaving actions are influenced markedly therefore by the body and mountings of the power-unit.

By the use of torsionally stiff cross-members, or by other means, the weave resistance of frames can be greatly improved, so that the frame itself may be counted on to take care of the weaving couple to a major extent. Such frames are designated herein as "weave resisting."

This paper presents an analytical investigation of the weaving stresses in such frames, neglecting any assistance that the frame members may receive from the body, or other parts. The analysis is confined to the case in which the weave resistance is obtained by the use of large tubular cross-members.

The frame structure selected for analysis is of the simplest form, namely, one having straight parallel side-rails of uniform cross-section. In applying the results to actual frames, the side-rails of which usually are neither parallel nor of uniform depth, some judgment is necessary. But, in practical applications, the most important weaving-stresses generally occur at or near the widest part of the frame, where the depth of the section is also at or near its maximum; and the appropriate depth and width of an "equivalent" frame to select for the stress determinations are found by trial calculations.

THE WEAVING COUPLE

The magnitude of the weaving couple is readily determined for any particular case. To fix our ideas, we shall consider an extreme case, not necessarily the most extreme, of practical importance, namely, when one spring is entirely bereft of load.

Fig. 1 represents schematically a front elevation of a motor-vehicle chassis. Under ordinary conditions, each spring carries a static load W. Now imagine the axle to become so tilted relatively to the frame, as shown by the dotted lines, that the load on one spring becomes zero. This will not alter the distribution of the load between the front and the rear, hence, the total load $2W$ will then be carried by the other spring.

It is clear that this change in load distribution is equivalent to impressing on the frame the couple

$$C_w = Ws$$

where

C_w = the "axial weaving-couple" due to the change of distribution of the load

s = the side-rail center distance

W = the normal static load on one spring

This couple must be balanced by an equal and opposite couple at the other end of the frame, hence, a change in the distribution of the load at one end of the vehicle will cause a corresponding change at the other end, accompanied by the same couple Ws.

The force impressed on the side-rail at each end, by virtue of these equal and opposite couples, is simply W. From Fig. 2, it is clear that the resultant forces on the side-rail consist of a couple

$$C_s = WL$$

where

L = the length of the wheelbase

S_s = the "transverse weaving-couple"

The couples C_s acting on the two side-rails are, of course, equal and opposite. They are transmitted to the cross-members by bending moments in the side rails and are resisted by torsional stresses in the cross-members. In the type of frame under consideration, in which the side-rails are torsionally weak and the cross-members torsionally stiff, the bending moments in the side-rails and the twisting moments in the cross-tubes represent the most important stress-system induced and are the only ones that will be considered. This procedure introduces no important discrepancies and makes the problem amenable to simple analysis by the common theory of flexure.

A clearer insight may be had by imagining that the cross-tubes are so fastened to the side-rails that they are capable of transmitting torsion only, that is, that they are incapable of transmitting shearing or bending stresses. If the side-rails are parallel, the effect of such fastening on the system of weaving stresses here considered is practically negligible.

CALCULATION OF WEAVING MOMENTS AND STRESSES

For sake of definiteness, we shall consider a side-rail, as shown in Fig. 3, having five cross-tubes of any diameters, one of which is shown at the front-spring front-hanger, another at the rear-spring front-hanger. Distances along the frame are measured from the front-spring front-hanger. The positions of the various tubes are given by their distances a, b and the like, from the first tube, as indicated in Fig. 3, where A is the length

[1] M.S.A.E.—Jackson Heights, N. Y.

of the front spring; B, the length of the rear spring; L, the length of the wheelbase; and so on. The axles are assumed to be fastened midway between the spring-eyes.

Any given weaving couple C_w gives rise to the equal and opposite forces $2F$ at the axles, as is shown in the case considered above, where one spring is bereft of load, $2F = W$, the normal load on the spring. The forces impressed on the frame are of magnitude F, spaced at the spring-eyes as shown.

The transverse weaving-couple is $2FL$, as has been pointed out above. Let M_1, M_2 and so on represent the moment acting on the first tube, second tube and so on. Then, in accordance with the foregoing,

$$\Sigma M = M_1 + M_2 + M_3 + M_4 + M_5 = 2\,FL$$

Let x be the horizontal distance, from the first tube, of any point in the frame; y, the deflection of the side-rail at that point, and BM, the bending moment in the side-rail at that point. Denote the moment of inertia of the section by I and Young's modulus by E. Then, according to the common theory of flexure, we have

$$d^2y/dx^2 = BM/EI; \tag{1}$$

and, as already shown,

$$\Sigma M = 2\,FL \tag{2}$$

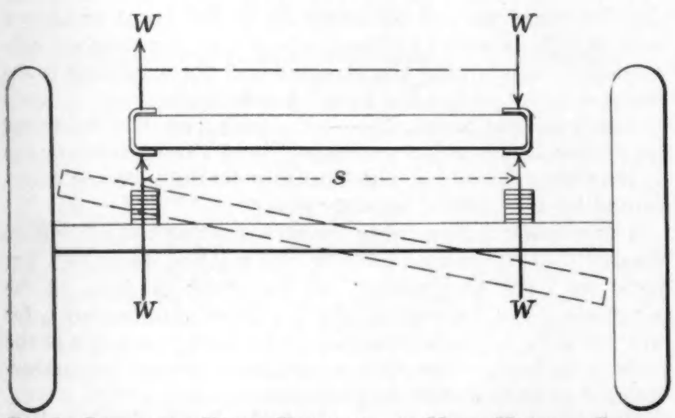

FIG. 1—SCHEMATIC FRONT ELEVATION OF MOTOR-VEHICLE CHASSIS
W Represents the Normal Static Load on One Spring; s, the Side-Rail Center-Distance. The Axial Weaving-Couple C_w Due to the Change of Distribution of the Load Is Equal to Ws

Analytically speaking, the side-rail shown has six sections. The first section runs from the first tube to the front-spring rear-hanger, that is, from $x = 0$ to $x = A$; the second section, from the end of the first section to the second tube, that is from $x = A$ to $x = a$, and so on. The expressions for the bending moments in each section may be written from inspection of the figure, and, with slight rearrangement, are as follows:

First Section, $BM = Fx - M_1$
Second Section, $BM = 2\,Fx - FA - M_1$
Third Section, $BM = 2\,Fx - FA - M_1 - M_2$
Fourth Section, $BM = 2\,Fx - FA - M_1 - M_2 - M_3$
Fifth Section, $BM = Fx + F(c - A) - M_1 - M_2 - M_3 - M_4$
Sixth Section, $BM = M_5$

Introducing these expressions, in turn, into equation (1), integrating twice in each case, and denoting the constants of integration by K_1, K_2, K_3, and so on, we have:

First Section,

$$\left.\begin{aligned} EI\ dy/dx &= 1/2\ Fx^2 - M_1x + k_1 \\ EI\ y &= 1/6\ Fx^3 - 1/2\ M_1x^2 + k_1x + k_2 \end{aligned}\right\} \tag{3}$$

Second Section,

$$\left.\begin{aligned} EI\ dy/dx &= Fx^2 - FAx - M_1x + k_3 \\ EI\ y &= 1/3\,Fx^3 - 1/2\,FAx^2 - 1/2\,M_1x^2 \\ &\quad + k_3x + k_4 \end{aligned}\right\} \tag{4}$$

. . . .
. . . .

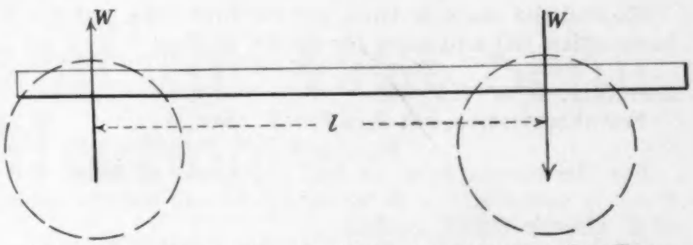

FIG. 2—TRANSVERSE WEAVING-COUPLE ACTING ON THE SIDE-RAIL
The Resultant Forces Acting on the Side-Rail Consist of a Couple, $C_t = WL$, Where W Is the Force Impressed on the Side-Rail at Each End, by Virtue and Opposite Couples, and L the Length of the Wheelbase

Sixth Section,

$$\left.\begin{aligned} EI\ dy/dx &= M_5x + k_{11} \\ EI\ y &= 1/2\,M_5x^2 + K_{11}x + K_{12} \end{aligned}\right\} \tag{5}$$

It will be seen that each section gives rise to two constants of integration, so that we have altogether 12 such constants k_1, k_2 k_{12}. We determine 10 of these constants from the fact that the deflection y and slope dy/dx at the end of any section is equal to the deflection and slope at the beginning of the next section. Thus, putting $x = A$ in (3) and (4) and equating the slopes:

$$_1[dy/dx]_A = {}_2[dy/dx]_A$$

gives

$$K_3 = 1/2\,FA^2 + K_1$$

Likewise, equating deflections

$$_1[y]_A = {}_2[y]_A$$

gives

$$K_4 = K_2 - 1/6\,FA^3$$

Proceeding in this way, we arrive at expressions for the K's as follows:

$$\begin{aligned}
K_5 &= K_1 + 1/2\,FA^2 + M_2a \\
K_6 &= K_2 - 1/6\,FA^3 - 1/2\,M_2a^2 \\
K_7 &= K_1 + 1/2\,FA^2 + M_2a + M_3b \\
K_8 &= K_2 - 1/6 - BA^3 - 1/2\,M_2a^2 - 1/2\,M_3b^2 \\
K_9 &= K_1 + 1/2\,F\,(A^2 - c^2) + M_2a + M_3b + M_4c \\
K_{10} &= K_2 - 1/6\,FA^3 + 1/6\,FC^3 - 1/2\ (M_2a^2 + M_3b^2 + M_4C^2) \\
K_{11} &= K_1 + 1/2\,F\,(A^2 - C^2 - D^2) + M_2A + M_3b + M_4C \\
K_{12} &= K_2 - 1/6\,(A^3 - C^3 - D^3) - 1/2\,(M_2a^2 + M_3b^2 + M_4C^2)
\end{aligned}$$

We have now to determine the two remaining constants K_1 and K_2, K_2 being arbitrary, and the five moments $M_1 \ldots\ldots M_5$ acting on the tubes.

Regarding each cross-member as a torsional spring, the moment exerted by it is given by the product of its torsional stiffness and the angle of twist. The stiffness is readily calculated from the dimensions of the tube; the angle of twist is simply the slope dy/dx of the frame at the point of the anchorage. For small angles, dy/dx = the slope = the tangent = the sine = the angle.

Denoting the stiffness of any tube by T_n, the corresponding slope by $[dy/dx]_n$ and the corresponding moment by M_n, n varying from 1 to 5, then

$$M_n = T_n\,[dy/dx]_n$$

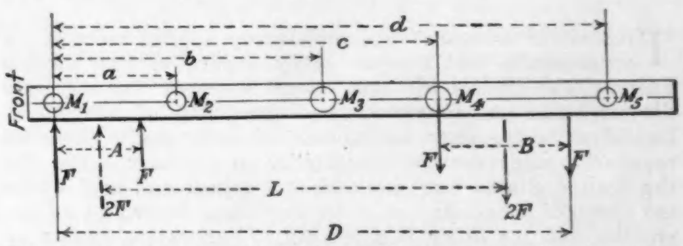

FIG. 3—ANALYSIS OF THE WEAVING MOMENTS AND STRESSES ON A SIDE-RAIL
The Side-Rail Is Considered as Having Five Cross-Tubes of Any Diameters, One of Which Is Shown at the Front-Spring Front-Hanger, Another at the Rear-Spring Front-Hanger. Distances along the Frame Are Measured from the Front-Spring Front-Hanger and Are Indicated by a, b, c, and d. A Is the Length of the Front Spring, B, the Length of the Rear Spring and L, the Length of the Wheelbase. The Axles Are Assumed To Be Fastened Midway between the Spring-Eyes

To find the angle of twist for the first tube, put $x = 0$ in equation (3) and solve for dy/dx, getting

$$[dy/dx]_1 = K_1/EI$$

therefore, $M_1 = K_1T_1/EI$.

For abbreviation, put $T_1/EI = Z_1$, then,

$$M_1 = K_1Z_1$$

For the second tube, to find the angle of twist, put $x = a$ in equation (4), solve for dy/dx and use the value of K_1 already found, getting

$$[dy/dx]_2 = 1/EI\ [F\ (a^2 + 1/2\ A^2 - Aa) + K_1(1 - (T_1a)/EI)]$$

For abbreviation, put

$$V_2 = (T_2/EI)\ F\ (a^2 + 1/2\ A^2 - Aa)$$
$$Z_2 = (T_2/EI)\ (1 - T_1a/EI)$$

then

$$M_2 = T_2\ [dy/dx]_2 = V_2 + K_1Z_2$$

Proceeding in the same way to find $[dy/dx]_3$ and the like, and M_3 and the like, writing the results in abbreviated form and assembling the results, we find:

$$M_1 = K_1Z_1$$
$$Z_1 = T_1/EI$$
$$M_2 = K_1Z_2 + V_2$$
$$V_2 = (T_2/EI)\ F\ (a^2 + 1/2\ A^2 - Aa)$$
$$Z_2 = T_2/EI\ (1 - Z_1a)$$
$$M_3 = K_1Z_3 + V_3$$
$$V_3 = T_3/EI\ [F\ (b^2 + 1/2\ A^2 - Ab) - V_2\ (b - a)]$$
$$Z_3 = T_3/EI\ [1 - Z_1b - Z_2\ (b - a)]$$
$$M_4 = K_1Z_4 + V_4$$
$$V_4 = T_4/EI\ [F\ (c^2 + 1/2\ A^2 - Ac) - V_2\ (c - a) - V_3\ (c - b)]$$
$$Z_4 = T_4/EI\ [1 - Z_1c - Z_2\ (c - a) - Z_3\ (c - b)]$$
$$M_5 = K_1Z_5 + V_5$$
$$V_5 = T_5/EI\ [F\ [2\ Ld + 1/2\ (A^2 - D^2 - C^2)] - V_2\ (d - a) - V_3\ (d - b) - V_4\ (d - c)]$$
$$Z_5 = T_5/EI\ [1 - Z_1d - Z_2\ (d - a) - Z_3\ (d - b) - Z_4\ (d - c)]$$

Thus, we have determined the five moments M_n in terms of the quantities Z_n, V_n and T_n, all of which can be calculated from the frame design and the weaving force F, and in terms of the constant K_1. This constant is now immediately determined from equation (2), as follows:

$$\Sigma M_n = K_1\Sigma Z_n + \Sigma V_n = 2\ FL$$

therefore

$$K_1 = (2\ FL - \Sigma V_n)\ \Sigma Z_n$$

Hence, the problem is completely determined. The bending moments on the side-rails may now be calculated by direct substitution, in the bending-moment equations, of the values of M_1, M_2 . . . . thus found, and the stresses can then be figured in the usual way from the bending moments and the section moduli. The deflections and slopes may also be calculated by equations (3) . . . . (5), using the values of K_1, ... K_{12} subsequently determined.

It should be noted that K_2, which enters into the deflection formulas only, is arbitrary. This signifies that we may call the deflection zero at any desired point in the frame and determine all other deflections relatively to that point. For example, if we arbitrarily consider the deflection zero at the first tube, that is, if we let $y = 0$ when $x = 0$; then, from equation (2), $k_2 = 0$.

It should be noted that the weaving stresses here determined are superimposed on the stresses determined from the usual static calculations and are to be algebraically added to these static stresses.

Tapered Frames

It is clear that the weaving forces F at the two ends of the frame, front and rear, are in the inverse ratio of the width of the frame at those ends. The case we have considered is one having parallel side-rails, so that the width of the frame and, hence, forces F are alike, front and rear.

The case of the tapered frame can be handled by taking first that part of the force F_f, at the front or narrow end, which is equal to the force F_r at the rear or wide end, and determining the stresses and deformations in the same manner as for the parallel-side frame.

The residual force, $F_f - F_r$, acting at the front end may then be regarded separately, and the stresses due to it may then be added algebraically to the stresses determined by the method already given.

The method determining the stresses due to the residual force $F_f - F_r$ is analogous to the method described, but here we have to consider the shearing stresses in the cross-members, instead of the torsional stresses only, for the force $F_f - F_r$ is balanced by shearing stresses in the cross-members. The solution is therefore more cumbersome than that of the simpler case.

From my experience in calculating such frames, it is hardly necessary, in cases of conventional side-rail design, to go farther than the simple example given, for reasons already indicated.

Furthermore, although five tubes were shown in the case treated, the actual computation for frames of practical design may be considerably simplified by limiting the analysis to the cross-members that play a dominant role in resisting the weave.

ASBESTOS

THE term "asbestos" is commercially applied to varieties of minerals that can be easily separated into flexible fibers. The properties that make asbestos valuable are fibrous structure, toughness and flexibility of the fibers, incombustibility, slow conduction of heat, high electrical resistance, and practical insolubility in ordinary acids. In the United States two minerals are mined and sold under the name of asbestos; one is an amphibole known as anthophyllite and the other is a variety of serpentine known as chrysotile. These two minerals are similar in many of their physical properties and have approximately the same heat-resisting qualities but chrysotile, in addition to being a poor conductor of heat and electricity, is superior in tensile strength. Its fibers are tougher and more elastic, thereby rendering it desirable for many purposes for which anthophyllite is not suitable. Toughness and relative infusibility are the qualities upon which the commercial value of asbestos chiefly depends. Chrysotile asbestos is more easily decomposed by strong acids than anthophyllite, and for use as chemical filters anthophyllite is considered to be the preferable material.

The United States is the largest manufacturer and consumer of asbestos products in the world, but the asbestos used comes almost wholly from Canada. In 1925 producers in the United States sold 1258 net tons of asbestos, and imports amounted to 230,520 net tons, of which 225,938 tons came from Canada. Thus it will be seen that the quantity mined in this Country is insignificant. The Canadian material is wholly chrysotile asbestos, whereas that produced in the United States is both chrysotile and anthophyllite; in 1925 the greater proportion was anthophyllite.—B. H. Stoddard in a Bureau of Mines Bulletin.

Discussion of Papers at the 1926 Semi-Annual Meeting

THE discussion following the presentation of two of the papers at the Semi-Annual Meeting of the Society that was held at French Lick Springs, Ind., in June, 1926, is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication. For the convenience of the members a brief abstract of each paper precedes the discussion so that members who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in THE JOURNAL can do so easily.

This completes the publication of the discussion of the papers presented at the 1926 Semi-Annual Meeting. Discussions of other papers presented at this meeting were published in December, 1926, and January and March, 1927, issues of THE JOURNAL.

VOLATILITY TESTS FOR AUTOMOBILE FUELS

BY T. S. SLIGH, JR.[1]

ABSTRACT

ELEMENTARY theories regarding the evaporation characteristics of pure substances and mixed liquids are discussed briefly and the difficulties likely to be encountered in attempts to calculate the volatilities of motor fuels from data relating to pure substances or in the extrapolation of volatility data corresponding to the atmospheric boiling-range of the fuel to the range of temperatures encountered in utilization of the fuel are pointed out. A brief review of previous methods of arriving at fuel volatility is also presented.

Volatility, as applied to motor fuels, is defined as being measured by the percentage of a given quantity of the fuel which can be evaporated under equilibrium conditions into a specified volume. The weight of air under known pressures is taken as a convenient measure of the volume.

The new method described is an equilibrium distillation of the fuel in the presence of a known weight of air. The fuel is supplied at a predetermined rate by displacement from a reservoir by the fall of a clock-controlled cylinder, and flows into a long metal helix immersed in a bath at the temperature of the test. Air is also delivered to this helix at a predetermined rate, as measured by a small-orifice meter. Evaporation takes place to equilibrium, and the uncondensed fuel is drained from the lower end of the helix and measured. By such means the distillation curve for the fuel in any desired air-fuel mixture can be determined accurately.

Data are presented for five fuels of varied characteristics which had also been used in engine tests of starting volatility. Such volatility data will be useful in connection with studies of engine performance, carburetion, the blending of fuels, and the production of fuels for specified performance.

The importance of the very low end of the distillation curve for the fuel that is distributed generally throughout the United States is emphasized in the discussion. —[Printed in the August, 1926, issue of THE JOURNAL.]

THE DISCUSSION

RALPH H. SHERRY[2]:—Has Mr. Sligh made any curves on olefine and naphthene, and on olefine and naphthene mixtures with commercial gasoline?

T. S. SLIGH, JR.:—All gasoline contains a fairly large percentage of those compounds. I have not picked out particular compounds to work with. The calculations for the pure compounds, of course, were made solely from experimental data. The composition of the gasolines is not known. They were just commercial gasolines. I have no specific data on the naphthenes and olefines.

MR. SHERRY:—I believe it would be of interest in view of the fact that attention is being called to the value of naphthenes particularly.

QUESTION:—Where can we get the pure naphthene commercially?

MR. SHERRY:—It is not so much a matter of commercial naphthenes, but motor spirit of antiknock value is being made in Toledo, and attention has been called to the naphthene content of Western gasolines. If it is possible to add to Mr. Sligh's data information of the same kind on naphthene and olefines, it would seem of value for comparative purposes.

QUESTION:—Does the rate of air and of fuel flow approximate manifold-velocities at starting speeds?

MR. SLIGH:—Not at all. The air-fuel ratio was the same. The velocity affects the time-rate as to attainment of equilibrium. In this apparatus it was desirable to obtain equilibrium conditions regardless of how long fuel had to be supplied.

O. C. BERRY[3]:—The work reported in Mr. Sligh's paper is of great value to the refiner and to the man who designs carbureters and manifolds for the use of present motor fuels. To my mind there is a difference in the comparative value of different parts of the distillation curves, no matter which method is used in getting this standard of measurement of volatility. Probably all automotive engineers will agree that it is highly desirable to be able to operate our passenger-cars on one grade of fuel and not have one fuel for starting and another fuel to operate on. That being the case, it will be necessary for us to use richer mixtures for starting than after the engines are warmed-up.

I think the figures indicating the richness of mixture desirable for starting, presented by Mr. Sligh, are somewhat optimistic. We do not find that 2 lb. of air per pound of gasoline is a desirable mixture for starting in very cold weather but, rather, 2 lb. of gasoline per pound of air. And 3 lb. of gasoline per pound of air is distinctly superior to 2 lb. of gasoline per pound of air when start-

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[2] M.S.A.E.—Consulting metallurgist, Evanston, Ill.

[3] M.S.A.E.—Chief engineer, Wheeler-Schebler Carburetor Co., Indianapolis.

ing cars in the Northern part of the United States. This means that we do not come close to perfect equilibrium in the manifolds of cold engines and helps to explain the importance of the very low end of the distillation curve for the fuel that is distributed generally throughout the United States.

When it comes to starting an engine, the man who makes the carbureter has been handicapped. He has a cold engine, cold fuel and cold air and must start the engine under those conditions. He is dependent upon the volatility of the fuel and on the fuel-air ratios in determining whether or not the engine will start and how much time will elapse before the first explosion occurs. From that point on he does have some factors that are under his control. He can use a hot-spot in which the heat capacity of the metal involved in the hot-spot is very low, so that the application of a small amount of heat will make a difference in the temperature of the metal in the hot-spot. He can then construct his apparatus so that the exhaust from all the cylinders is concentrated on this hot-spot, so that it will be heated quickly. In these ways he can shorten the warming-up period to a very marked degree. Therefore, it seems to me that the very low end of the distillation curve is much more important than the middle range.

We find that any of our fuels are satisfactory after the engine is warmed-up. We are not worried particularly about the end-point of a fuel so far as getting carburetion is concerned, although of course the man who has trouble on account of dilution of the lubricating-oil is interested in the end-point. The man who designs the carbureter and the manifold is not interested in the end-point; he is interested in the middle range to a certain extent, but he is very seriously interested in the lower end of the distillation curve.

I want to recommend to the refiners that they make a very much more marked distinction between summer gasoline and winter gasoline in the future. We all appreciate the difficulty that the refiner meets in storing up large quantities of very volatile hydrocarbon. It is a very difficult matter. It seems to me, however, that a much more marked distinction is possible than has ever been made in the past.

R. R. MATTHEWS[4]:—Was the No. 6 gasoline, the regular gasoline used by the Government, purchased to meet the United States Motor Gasoline Specifications?

MR. SLIGH:—I presume that it was bought to meet those specifications. It is the tail-end of a rather large supply, 1000 gal. or so, that we had and the distillation curve probably will not agree exactly with the one previously published on work that was done 6 months ago.

CHAIRMAN H. C. MOUGEY[5]:—We have experienced the same thing a number of times ourselves in that we started work with one kind of gasoline and, unless it was very carefully handled and watched, it was possible to lose some of the light ends of that gasoline while working with it. In some of our early work, we were badly misled by not taking precautions to watch that point.

DESIGN, PRODUCTION AND APPLICATION OF THE HYPOID REAR-AXLE GEAR

BY ARTHUR L. STEWART[6] AND ERNEST WILDHABER[7]

ABSTRACT

AFTER defining hypoid-gears and outlining their action, together with their general characteristics and advantages, the authors compare them specifically with spiral-bevel gears and follow this with a description of how the axis of the pinion is offset from the axis of the gear and how the direction of the offset determines whether the spiral is right-handed or left-handed.

Considering pitch-lines, details of the mesh between a crown-gear and an offset pinion are presented, since this constitutes a special case of hypoid-gearing, and the application of these principles to a pair consisting of a pinion and a tapered gear is discussed. The rate of endwise sliding, the proper ratio of gear-diameters, tooth loads and tooth profiles are other phases treated specifically, and computations of surface stresses by the Hertz formulas, with special reference first to a comparison between helical teeth and straight teeth, and then with reference to hypoid-gears, are outlined.

Following a description of the newest method for the production of hypoid-gears and a statement of the machining operations needed, it is pointed out that the finish-cutting of the pinion is the only major operation which requires machinery different from that used for the production of spiral-bevel gears and pinions.

Outstanding points covered in the discussion include statistics and comment on actual pressures on the teeth of spiral-bevel and hypoid-gears; maximum amount of offset allowable for hypoid-gears; distortion of pinions due to heat-treatment; and additional considerations relating to the respective merits of "overshot" and "undershot" mountings.—[Printed in the June, 1926, issue of THE JOURNAL.]

THE DISCUSSION

A. L. STEWART:—Due credit must be given Nikola Trbojevich for his important work. In patents already issued or now pending, he used new methods of analysis which were of material assistance in the first steps of the work which has been done at the Gleason Works. He also disclosed new forms of gears of the general curved-tooth hypoid-class. Reference is made to his articles[8] describing his work in hobbing spiral-bevel gears and including the curved-tooth gears of the hypoid-gear class which he had developed.

The developments here under discussion are the work of Ernest Wildhaber, made independently of Mr. Trbojevich but subsequently to what he did and with a knowledge of what he did. Several important steps had to be taken by Mr. Wildhaber before the present development could be offered in practical form; (a) the solution of the mesh between curved pitch-lines had to be made general where it previously had been made for only one specific case; (b) circular arcs were used in place of various more complicated curves, and a simple and essential method of determining radii of curvature was originated; (c) the solution of the mesh between curved pitch-lines was extended to two tapered-gears, so that the problem was analyzed in three dimensions instead of two

[4] M.S.A.E.—Lubrication division manager, Roxana Petroleum Corporation, St. Louis.

[5] M.S.A.E.—Chief chemist, General Motors Corporation Research Laboratories, Detroit.

[6] M.S.A.E.—Chief engineer, Gleason Works, Rochester, N. Y.

[7] Research engineer, Gleason Works, Rochester, N. Y.

[8] See *American Machinist*, Nov. 1, 1923, p. 647; see also *Machinery*, November, 1923, p. 165.

only, as had been formerly done and, obviously, this cannot be done by the use of developments in a plane.

The important feature of the present disclosure is that for the first time there is offered a system of curved-tooth hypoid-gears having generated profiles along with a highly practical and commercial method of producing them. This statement is made to give proper credit to each inventor. It is unnecessary, so far as the patent situation is concerned, since all of the issued and pending patents of Mr. Trbojevich having to do with the hypoid-gear development, as well as those covering the hobbing of spiral-bevel gears, are owned by the Gleason Works.

CHAIRMAN C. D. MCCALL[9]:—What effect will higher pressure-angle, higher spiral-angle and greater sliding-action have on tooth design? Most gear producers have been using the Gleason system of tooth design. Is any modification of that system likely because of hypoid-gears?

MR. STEWART:—We have made no such modification. Some actual figures in regard to the pressures on the teeth are as follows: For a pair of gears having 13 and 61 teeth, respectively, 2-in. offset and 12-in. pitch-diameter, the diameter of the pinion is increased from 2.30 to 2.70 in., a gain of 0.40 in., by changing from spiral-bevel to hypoid-gear, on a 2.25-in. basis. In the case of hypoid-gears, the tooth loads mainly turned out to be less, even though the spiral angles are somewhat higher on the pinion and the pressure angles somewhat higher also. For instance, in the pair just mentioned, considering the tooth load on the pinion for every 1000 lb. of tangential tooth-load on the gear, we have the following figures: For the spiral-bevel gear the normal tooth-load, that is, the resultant of all components, is 1193 lb., while for the hypoid-gear it is 1090 lb., which is considerably less. The axial thrust of the pinion in the spiral-bevel gear pair, 620 lb., increases in the hypoid-gear pair to 649 lb. on the forward drive, and on the reverse drive it reduces from 495 to 489 lb. The radial pressure on the forward drive increases from 170 lb. on the bevel-gear pair to 182 lb. on the hypoid-gear pair and, in reverse drive, it increases from 410 to 498 lb. Other figures that are available bear out these same relationships.

General statements made by engineers of the bearing manufacturers indicate that bearings required for hypoid-gears will, in general, be the same as for the pair of spiral-bevel gears which they replace; that is, the loads have not changed enough to make any radical difference in bearing requirements. That statement must be checked up in each particular case according to the design, and it is made only as a general key to the situation so far as the loads on the bearings are concerned.

H. E. BRUNNER[10]:—Are hypoid-gears less sensitive to radial and to lateral yield than the helical-bevel gears?

MR. STEWART:—They are about the same. It would not be a fair statement to say that there is any great difference either way. The flexibility of control of the bearing when producing the hypoid-gear enables the producer of the gears to place that bearing in amount and in location to exactly the best advantage. It is much more easily done than in the case of either straight or spiral bevel-gears.

QUESTION:—If mounted in straddle bearings, is any less room available for the inner bearing in the case of hypoid-gears?

MR. STEWART:—Because the hypoid-pinion is offset from the center of the gear, it is not so convenient for use with a straddle mounting. The design must be worked out carefully and all advantage possible must be taken of the space available so as to get the straddle mounting in, but it is a possible arrangement.

M. C. HORINE[11]:—A pinion that had been used for 12,000 miles showed that a small triangular space at the back end of each tooth had not been in contact with the gear. Why cannot that particular portion of the tooth be eliminated so that it would be possible to get a more favorable arrangement of flow-lines in the forging?

MR. STEWART:—The only practical objection is that it takes a different direction on the drive side from that on the reverse side. It is not practicable to cut that part out from the whole end of the tooth. The best that can be done after the tooth has been produced is to cut that part away by some succeeding operation, but that has not been found necessary so far.

OFFSET ALLOWABLE

C. S. CRAWFORD[12]:—What is the maximum amount of offset that can be used?

ERNEST WILDHABER:—It is not practicable to use too much offset, but an offset which is slightly larger than one-half the outside radius of the gear can be used.

CHAIRMAN MCCALL:—Is it thought that hypoid-gears will be applied to motor-trucks as well as to passenger-cars? What considerations are made in applying them, compared with the bevel-gears now used?

MR. WILDHABER:—The advantage of the hypoid-gear drive as compared with bevel-gear drives for motor-trucks lies in the fact that the pinion has a much larger diameter; therefore, larger reductions can be obtained. The pinion, which is usually a weak member, is much stronger.

ERNEST WOOLER[13]:—What material is recommended for hypoid-gears?

MR. STEWART:—The same as that used for spiral-bevel gears.

QUESTION:—Have any tests been made on the block or otherwise to determine the exact power losses of the hypoid and the spiral-bevel gears?

MR. STEWART:—No.

A MEMBER:—Due to the fact that the pinion has a larger diameter, there should be greater torque on the pinion-shaft to get the same amount of torque in the rear axle. How is that taken care of? Does the angle of the tooth and the sliding take care of it? Is there a loss of power there? It seems to me that the larger the pinion is, the greater is the amount of torque it must exert on the driveshaft to give the same torque on the rear-axle gear.

MR. WILDHABER:—We use the same ratio as for the same reduction on spiral-bevel gears. The friction loss is very small; therefore, the ratio of the torque transmitted to the pinion-shaft is exactly the same. If there is a certain amount of torque on the gearshaft, we must transmit a corresponding amount of torque to the pinion-shaft without any change.

DISTORTION DUE TO HEAT-TREATMENT

E. S. MARKS[14]:—Will the change in the shape of the tooth on the pinion make the pinion any more susceptible to distortion caused by heat-treatment?

[9] Chrysler Corporation, Detroit.

[10] M.S.A.E.—Chief engineer, S.K.F. Industries, Inc., New York City.

[11] M.S.A.E.—Sales promotion engineer, International Motor Co., New York City.

[12] M.S.A.E.—Chief engineer, Stutz Motor Car Co. of America, Inc., Indianapolis.

[13] M.S.A.E.—Chief engineer, Timken Roller Bearing Co., Canton, Ohio.

[14] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

MR. STEWART:—The change in shape as compared with spiral-bevel pinions consists usually of a slightly higher angle of spiral, a radius of curvature somewhat greater than that of the cutter which produces the pinion and the longer tooth. All I can say is that the experience we have had so far does not indicate any more difficulty in that direction. In fact, on several sample jobs in which allowance was made for changes of the pinion, no change occurred and we had to recut the hardened pinions to exactly the bearings we wanted.

MR. HORINE:—As I understood Mr. Stewart, the so-called overshot type of mounting in which the pinion is higher than the center of the gear was reported as having disadvantages and as not being as efficient a gear as the undershot type. Would that not rather definitely preclude its use on motor-trucks? It is necessary to have a high frame on a motor-truck; consequently, the overshot type of drive is necessary. Is there some possibility of obtaining satisfactory efficiency and durability with the overshot type?

CHAIRMAN MCCALL:—A motor-truck axle generally can be made much heavier than can the rear axle of a passenger-car; therefore, it can be built to be more rigid and will thus take care of that inward thrust more effectively than is possible in the passenger-car axle.

MR. STEWART:—The difference in the intimacy of contact on the two sides is very slight. On a pair of these gears developed in the cutting, if the contacts that are produced on the drive side and on the reverse side are compared, I doubt that anyone could detect that difference in the amount of tooth-surface contact. As we said at the start, the paper is and had to be based largely on theoretical and analytical considerations.

RANGE OF GEAR-RATIOS

L. R. BUCKENDALE[15]:—What practical ranges in ratio have been traced out with the hypoid-gear system?

MR. STEWART:—So far, we have used ratios as low as 4 to 1, and we also have used 6½ to 1. We have jobs under way of 7 to 1 and 8 to 1, with which we anticipate no difficulty. We have laid out jobs, although they have not been followed through, of 11 to 1; but there seemed no reason that we could not have proceeded to produce those gears and why we should not have found them entirely satisfactory.

A MEMBER:—In connection with gear-reduction, if a certain maximum gear-size is maintained and the ratio is increased, it seems to me that the helix angle of the pinion must be increased. That would affect the reversibility, would it not? That is, if the gear is converted into a driver and the pinion into a follower, there might be a wedging or rocking action there with too steep a helix angle on the pinion. How far would one dare go in using a steep helix-angle and still prevent that locking?

MR. WILDHABER:—As far as 60 or 65-deg. spiral-angle or helix-angle on the pinion.

QUESTION:—To what ratio does that correspond?

MR. WILDHABER:—To about a 15 to 1 ratio.

QUESTION:—Comparing the two types of gear, would there be a very great difference in the friction drop through the gears due to very stiff lubricant that might be used in cold weather?

MR. STEWART:—We have not expressed endwise sliding in absolute terms. We have expressed it as a proportion. Comparing a worm-drive, for instance, in which the angle was 45 deg., with a pair of hypoid-gears, the average amount of endwise sliding would be about 25 per cent in the hypoid-gears, just what it would be in the worm-drive for the same amount of peripheral movement.

QUESTION:—Meaning that the friction loss would be greater than with the spiral-bevel gear, due to the lubricant?

MR. STEWART:—There is an amount of endwise sliding which should be taken into account.

MANNER OF MOUNTING

MR. CRAWFORD:—Is it not true that most of your experimental work is with the drop-center mounting?

MR. STEWART:—Yes, but one axle shortly will have the pinion mounted above the gear.

MR. CRAWFORD:—I understand that the amount of drop which can be used is limited and that this limits the distance that the body can be dropped to get it closer to the ground.

MR. STEWART:—There is no theoretical limit to the amount of drop that can be used. We do not know the limit from practical experience as yet. On one job we have a 2-in. and on another job a 2½-in. drop, I think a 3-in. drop could be used just as well.

MR. CRAWFORD:—I think a 3-in. drop is not worthwhile. The drop should be at least 5 in, and if the drop is 7 in. the conditions are that much better.

MR. WILDHABER:—The more the offset is increased, the more sliding is increased, with a corresponding reduction in efficiency.

MR. CRAWFORD:—I think that the drive constitutes a disadvantage in that it hampers low center-of-gravity construction. The amount that the center of gravity can be lowered is limited very materially if one is forced to use a straddle mounting for the pinion.

MR. WILDHABER:—You are not forced to use straddle mounting for the pinion.

MR. STEWART:—The percentage of straddle-mounted spiral-bevel jobs submitted to us for redesigning as hypoid-gears was not high. In most cases the hypoid-gears replaced the spiral-bevel pair in which the pinion already had an overhung mounting. So far as position of the spiral-bevel pinion is concerned, there has been no limitation as to the use of the straddle mounting. The majority of the jobs that have been submitted already had an overhung mounting.

T. C. SMITH[16]:—With a so-called overshot gear, if the bearing were not properly adjusted so that the pinion slid too far back into the mesh, would there be a tendency for the pinion to be drawn into the following gear and to cause teeth to break?

MR. STEWART:—The character of that action is exactly the same as in the case of spiral-bevel gears. That condition always exists on the reverse drive of a left-hand spiral-bevel drive. Sufficiently rigid bearing-mountings can be made so that they will entirely offset any tendency toward such movement. It is true that such movement of the pinion in the gear, which is a wedging action, is dangerous and is not desirable. We have made many tests of rear axles to prove definitely just what amount of pinion and of gear displacement there is under heavy loads. We have found many axles in which that displacement was such as to interfere seriously with the proper operation of the gears.

Any pair of gears must operate in correct position and with the minimum of displacement. The gears are cut to run properly and to run in proper position. The result of the series of tests that we have conducted has been to stiffen the axles. A second test on the same axle after

[15] M.S.A.E.—Sales and development engineer, Timken-Detroit Axle Co., Detroit.

[16] M.S.A.E.—Engineer in charge of automotive labor-saving apparatus, American Telephone & Telegraph Co., New York City.

stiffening it has shown a very material improvement. Bevel-gears of any kind must be held in proper place and within reasonable limits. As soon as gears get out of position, they work at a disadvantage. A larger sized bearing or a different bearing-arrangement are means of holding gears in proper position.

MR. BRUNNER:—I had that same thought in mind when I asked the question about the sensitiveness of yield. If the hypoid-gears are no more sensitive to yield than are the spiral-bevel gears, it strikes me that the problem is no different, so far as locating the two gears in proper position is concerned.

HEAT-TREATED BOLTS

BOLTS, with which may be included other types of screw fastening, such as studs and set-screws, are frequently applied without proper consideration of the problems involved. Motor-car designers seldom make calculations of the size and number of bolts required for many purposes, relying upon experience in making a suitable selection. To check the sizes of important bolts is, of course, customary but even this is sometimes done in a rather perfunctory manner. As a consequence, wide differences are found in the practice of various motor-car builders, and troubles frequently arise in service. Insufficient attention is paid to the selection of material and to workmanship, and only too often bolts are purchased from outside sources of supply almost entirely on a basis of price. Even where bolts are made in the car factory, the tendency is to use the cheaper qualities of steel and to cut the machining times until both accuracy and finish suffer.

The usual material for bolts and other screw fastenings is low-carbon steel, commonly known as mild steel, but alloy steels are frequently used by the better class of manufacturers in the more important applications. Plain carbon-steel of rather higher carbon-content also is used for bolts but in the heat-treated condition.

Even for relatively unimportant applications, such as the fastening of wings, lamp brackets, undershields, and the like, cheap steels are a poor investment. Considering the ever-present risk of failure of low-grade materials, and in view of the low torsional strength of this class of steel, a very high factor of safety must be applied. Indeed, for general purposes, a factor of 10 is not too high, this corresponding to a working stress of about 4500 lb. for a 20-ton steel. As a matter of fact, no conscientious designer should entertain the use of these cheap steels for any purpose whatsoever.

Steel having a minimum ultimate-strength of 26 tons may be worked at a nominal factor of safety of 8 with a working stress of about 7000 lb. For ordinary purposes this steel may prove fairly satisfactory but its relatively low strength still necessitates the use of fairly large bolts for any given load, and in the smaller sizes great care is required to obviate the twisting off of threads by the careless use of the spanner.

A very generally used steel for screwed parts in the better class of automobile work is a plain carbon-steel giving the minimum tensile-strength of 35 tons and having much better torsional strength than the milder steels. Owing to its greater uniformity and the better finish of the screw-threads, this steel may be worked at a lower factor of safety. For average work, a value of 6 may be used, corresponding to a stress of about 14,000 lb., but naturally the designer must exercise judgment.

Alloy-Steel Bolts

Where still greater strength and reliability are required and particularly where the bolts are likely to be subjected to shock loads, two alternatives are available. The first is to use an alloy steel, such as 3-per cent nickel steel which can be relied upon to give 45-tons ultimate tensile-strength with a yield-point not below 32 tons. This steel is rather expensive and does not machine well as plain carbon-steel. It is not particularly hard on the surface and is a little likely to "pick-up" where any fretting occurs, or when driven into a tight reamed hole. With a good resistance to shock and the minimum Izod-value of 40 ft-lb., nickel steel may be worked with a nominal factor of safety of 5, at which the stress will be about 20,000 lb. per sq. in.

For bolts that are to be yet more highly stressed, the ternary alloy-steels are essential, but these find few applications in the ordinary automobile. In racing cars and aircraft engines, where weight must be cut and cost is unimportant, they are widely used, but nickel-chrome steel bolts cost two or three times as much as those of good mild steel and therefore are out of the question in the case of low-priced automobiles. Owing to the difficulties attendant upon the manufacturers of these steels, very careful inspection at all stages is essential, and heat-treatment must be most carefully carried out after machining, the bolts being finally finished by grinding to diameter. Nickel-chrome steel should give an ultimate tensile-strength of at least 55 tons, with the minimum yield-point of 45 tons. By suitable tempering the strength may be increased but at the expense of the impact-test value, which must be the minimum of 40 ft-lb. on a standard test-piece. For a 60-ton steel the Izod figure may be 50 ft-lb.

Speaking generally, the adoption of bolts made from these high-tensile steels will not permit of any reduction in the size of bosses, lugs and flanges, because sufficient area must be provided to withstand the local crushing loads. Where the bolts pass through aluminum, increasing the sections and providing for large heads and washers under the nuts may even be necessary. Any saving in weight due to the use of the high-tensile steel is thus largely illusory, and such bolts can generally be usefully employed only in conjunction with parts of steel, such as connecting-rods.

Heat-Treated Carbon-Steel Bolts

The second alternative where bolts are required to have strengths greater than ordinary mild steel is to use a plain carbon-steel of rather higher carbon-content and to heat-treat this by a process of hardening and tempering. Using a medium-carbon steel, by changing the heat-treatment the ultimate tensile-strength can be varied frcm 40 to as high as 65 tons, but as a general rule bolts are tempered to between 40 and 50 tons ultimate-stress. With the lower ultimate-strength, the elongation is about 26 per cent and the reduction of area 65 per cent. At the same time the impact value in the Izod test is as high as 80 ft-lb. By slightly varying the heat-treatment, an Izod value of 40 ft-lb. can be obtained with the ultimate tensile-strength of 60 tons. As a general average, it may be accepted that the ultimate strength of the standard quality of bolts is 45 tons, with an Izod value of 70 ft-lb.

From these figures it will be evident that the heat-treated carbon-steel bolts compare very favorably with those of nickel steel. Further, with the same average tensile-strength, the Izod value is decidedly higher, and thus the resistance to shock loads should be better. It is reasonable to work with the same factor of safety as for nickel steel, and therefore the working stress may be taken at 20,000 lb. for the 45-ton tempered bolts.

Plain carbon-steel in the heat-treated condition is at least as reliable as the alloy steels, and the steel makers find much less difficulty in obtaining uniformity in quality and in test values. It machines more readily and to a better finish than alloy steel of the same strength, while dies and tools generally hold their cutting edges and dimensions better when used on carbon steel. Therefore, the expenses for tooling are reduced and there is less dimensional scrap. Heat-treatment is simple, and the risk of failure or of irretrievably ruining the material is less. The surface of a heat-treated carbon-

steel bolt is harder than that of a bolt of alloy steel of equal strength, and this is a valuable feature. Where nuts are to be removed and replaced very frequently, the harder surface of the threads prevents the rapid wear that takes place with softer steels. Driven bolts do not so readily become scored and are stiffer to resist bending. They stand-up better to shear loads and are not so likely to become cut-up when the fit is not exactly tight. Heat-treated bolts successfully resist the torsional loads due to the spanner, and the fine finish obtainable on the threads reduces such loads to the minimum.

Owing to their higher strength, as a general thing it is permissible to fit heat-treated bolts of a size smaller than bolts of good mild steel. Thus, although the heat-treated bolts, size for size, may cost from 15 to 20 per cent more than a bolt of mild steel, it is cheaper in use because a smaller size will suffice. In comparison with the very mild steels, in some cases bolts several sizes smaller may be used, the saving then being considerable. Incidental to the use of heat-treated bolts is the possibility of reducing the dimensions of flanges and bosses, with a general improvement in appearance and a saving in weight. To effect such a reduction in dimensions as to render feasible a very radical change in the design may even be possible.

Standardized pipe-joint flanges and similar parts have been worked out on the basis of using bolts or studs of ordinary mild steel, or, in many cases, even for black-iron bolts. This practice has in every case resulted in large and clumsy flanges, the dimensions of which might be considerably reduced were they to be redesigned on the basis of heat-treated bolts. Smaller flanges render it possible to work pipes where standard flanges would prevent their passage, and on automobile engines great improvements in appearance may be effected by the use of small studs or bolts with correspondingly neat flanges.

Bolts of heat-treated steel may be tightened up closer than those of mild steel, even in a size smaller, and therefore are less likely to work loose. Owing to the harder surfaces, the threads do not wear appreciably, and after dismantling it will usually be found that the same relative positions of nut and bolt will enable the split pin or other locking device to be used as before. The nuts and bolt heads resist the attacks of spanners very well, and the good appearance of the job is maintained. Where well-made bolts of heat-treated steel are used throughout, a distinct saving in the first cost as well as in dismantling and rebuilding in the repair department is effected, while fewer replacements will be required.

Consideration of all the factors leads to the belief that an unanswerable case can be made out for the use of heat-treated bolts in the construction of motor-cars, as in other mechanisms. They are lighter, cheaper and at the same time more reliable than ordinary steel bolts to perform the same duty. And they may be used in place of the vastly more-expensive alloy steel bolts that have already found considerable vogue. Only where the very highest possible strength is required, irrespective of cost, are they unable to compete. I believe that the use of bolts of heat-treated carbon-steel will rapidly extend.

When working with bolts of the small sizes so commonly used in automobiles, provision must be made for the torsional loads and the excessive stretching loads that may be applied by a careless mechanic.—A. C. Burgoine in *Automobile Engineer*.

MELBERT W. TABER

THE announcement of the death of Melbert W. Taber in Detroit on Feb. 17 came as a shock to his many friends in the automotive industry, especially to those who had been in closer contact with him in Detroit during the last 5 years and to those who had worked with him during the early days of his career in Lansing, Mich. His last sickness dates back more than 1 year and his unexpected death was the direct result of a serious operation performed in Detroit about 3 weeks prior to his demise. Mr. Taber was born at Manistee, Mich., in 1881, where he received his early schooling. His college education at the Michigan Agricultural College fitted him for mechanical engineering. He received the bachelor of science degree from that college in 1904.

After considerable experience in the manufacturing plants of Lansing, Mich., Mr. Taber entered the service of the Seager Engine Works, of Lansing, where he was in charge of the production of small engines until he left that company's service in 1909. In 1911 his work took him to Detroit with the Packard Motor Car Co., where he remained until 1917. During that period he designed the lay-out and supervised the installation of electrical equipment which at the time had many new applications in the automotive field. Later he also had charge of powerplant and buildings maintenance and designed much of the automotive testing and production equipment. After leaving the Packard Motor Car Co., he was made factory manager of the H. H. Robertson Co., manufacturer of roofing and skylights. In this production he remained for a number of years but returned to the automotive field in 1921 when he was appointed special representative of the Motor Wheel Corporation, of Lansing, in charge of the sale of steel wheels to the automotive industry in Michigan. As sales-engineer in this field Mr. Taber met great success and his work took him to Detroit in charge of the company's office in that city.

Mr. Taber became a member of the Society in 1922 and was an active and popular member of the Detroit Section. He was President of the Detroit Engineering Society in 1925.

HERBERT CHAMPION HARRISON

ANNOUNCEMENT was made in a cablegram from England dated March 6 of the death in London of Herbert Champion Harrison, president and general manager of the Harrison Radiator Corporation, Lockport, N. Y., aged 50 years. He was born on Oct. 4, 1876, in Calcutta, India, where his father, Edward Francis Harrison, was Controller General of the Indian Civil Service. He was educated in England at Rugby and at Oxford, graduating from Trinity College in 1900 with honors in chemistry.

After gaining experience in metallurgy in England, Mr. Harrison came to the United States in 1907 as vice-president of the Susquehanna Smelting Co. He sold the business to the Union Carbide Co., Niagara Falls, N. Y., in 1909 and became its consulting engineer. He was the inventor of the Harrison radiator. In 1912 he formed the Harrison Radiator Corporation and became its president. The corporation developed rapidly and a few years later was reorganized as a subsidiary of the General Motors Corporation, with branch offices and a plant in Detroit. He was elected to Member grade in the Society on June 23, 1913.

The Motor-Truck Tire in Its Relations to the Vehicle and to the Road

By J. A. BUCHANAN[1]

TRANSPORTATION AND SERVICE MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

ABSTRACT

IN motor-truck impact-reactions, the unsprung component is generally the major quantity and the force depends on four principal variables: tire equipment, load, speed and road roughness. The tire equipment that utilizes the greater time of duration for the reaction will cause the lower impact-forces. Increases in load, speed and road roughness increase the impact-reaction. Poor tire-equipment on rough roads may cause forces of 35 tons to be borne by both the truck and the road. Pneumatic tires rarely allow reactions greater than twice the static wheel-load. The impact reactions of a six-wheel truck approximate one-half those of an otherwise equivalent four-wheel truck having the same pay-load. Fifty per cent loss in the overall height of the tire multiplies the impact reaction by 2.5. Rolling resistance varies with the speed, the tire equipment and the road surface, and may reach a value of one-sixteenth the wheel-load. Gasoline consumption at 10 m.p.h. on solid tires equals that at 25 m.p.h. on pneumatic tires. Data concerning forward and sidewise skidding are given for wide ranges of conditions.

IN the broad field of the economics of motor-truck operation, certain aspects of the relations of the tire to the vehicle and to the road are of such importance that they have become the objects of considerable research by the Bureau of Public Roads, either alone or in cooperation with other interested agencies.

This paper aims to present some of the more important data that have resulted from these researches. A general view will be given of the effects of vehicle type, wheel load, tire equipment, speed, and road conditions on gasoline consumption, tractive resistance and impact reactions. The data herewith presented have been compiled from the following sources: (*a*) The motor-truck impact project[2] conducted cooperatively by this Society, the Rubber Association of America and the Bureau of Public Roads; (b) tests[3] conducted by the Bureau of Public Roads to determine the relative effects of four and six-wheel trucks on pavement slabs; (*c*) a project[4], conducted cooperatively by the Iowa State College and the Bureau of Public Roads, concerning tractive resistance and gasoline consumption; and (*d*) a cooperative project[5] conducted by the Johns Hopkins University and the Bureau of Public Roads, concerning the relation between static and impact strains in concrete. During the course of this investigation, information was developed on the effect of the height of the rubber in a truck-tire segment.

There seems to be a great dearth of public information concerning the wear of tires under service conditions. This is particularly true of truck tires. Researches have been instituted in the States of Kansas and Washington from which data should be available concerning the wear of automobile tires on passenger-cars.

The purpose of this paper is to present such data as have so far been made available to the public, on the subjects above enumerated. It is, for the greater part, more of the nature of a review than a strictly independent paper.

Tests so far conducted in the cooperative project on motor-truck impact may be placed in two natural groups. The first was a compilation of truck and tire data and included measurements of the vertical deflections and tread dimensions of the tires under static loads. Fig. 1 shows the general method of mounting a tire in a conventional testing-machine for the determination of its properties under static loads.

IMPACT TESTS

The second group was the impact tests in which the quantity sought was the total vertical reaction between the road surface and the truck wheel. This was expressed in pound units, or as a percentage of the static

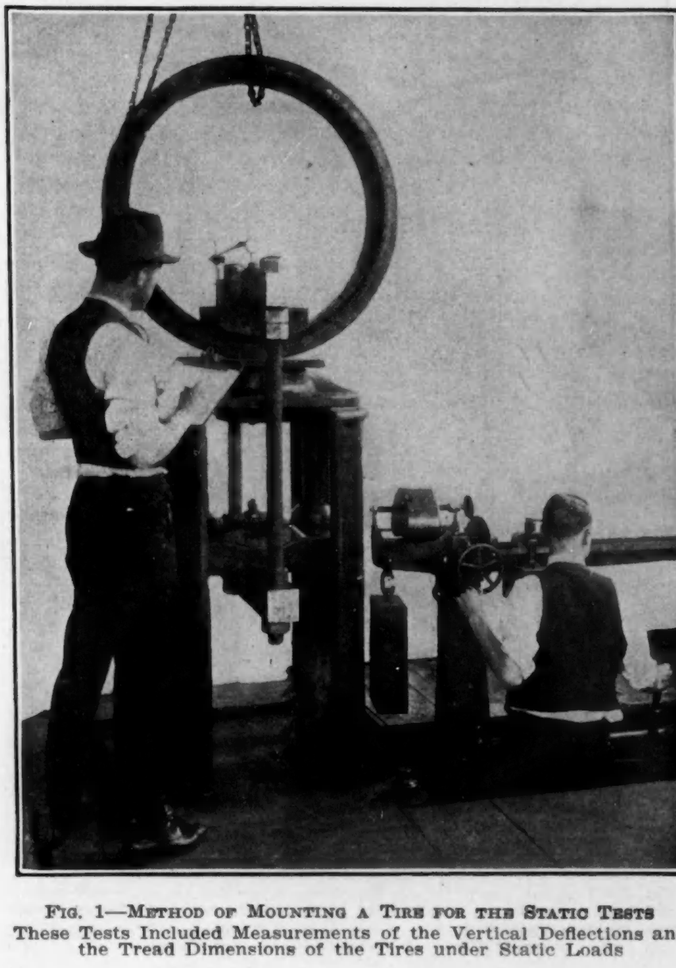

FIG. 1—METHOD OF MOUNTING A TIRE FOR THE STATIC TESTS
These Tests Included Measurements of the Vertical Deflections and the Tread Dimensions of the Tires under Static Loads

[1] Assistant engineer of tests, Bureau of Public Roads, City of Washington.

[2] See THE JOURNAL, June, 1926, p. 581.

[3] See *Public Roads*, October, 1925, p. 165.

[4] See Iowa State College, Engineering Experiment Station, Bulletin No. 67.

[5] See *Public Roads*, July, 1926, p. 93.

wheel-load, for the test conditions. The reaction between the road and the wheel should not be confused with riding-qualities, which are governed by other considerations, including the road reaction. Fig. 2 shows a typical test-truck equipped with the measuring apparatus which was specially designed, developed, and calibrated for these tests. The trucks varied in size from 1 to 5 tons and were equipped with tires of various sizes and types. They were operated at four loads, varying from the empty truck to 1.5 times the tire carrying-capacity. The speeds varied from 3 to about 20 m.p.h. The various heights and types of artificial obstruction that were used are shown in Fig. 3; the smooth and the rough sections of the actual highways used are shown in Fig. 4. In Fig. 5, the effect of the height of obstruction for the indicated test-conditions is shown. It is worthy of note that pneumatic tires did not allow an impact force greater than twice the static load, at least up to 2 in. in the height of the inclined plane, while the same truck, load, and speed developed an impact reaction of twice the static load, when worn-out solid-tires passed over an inclined plane only 0.15 in. in height. It is also seen that worn-out solid-tires caused an impact reaction of more than nine times the static load at the 2-in. height, but that the same tires, when new, caused only one-half the impact force that they caused in the worn-out condition. At speeds between 15 and 20 m.p.h., pneumatic tires carrying 4000 lb. per wheel did not cause reactions as great as 4 tons for this test-condition. The worn-out solid-tires at the same speed and carrying only 3400 lb. per wheel caused reactions of nearly 20 tons.

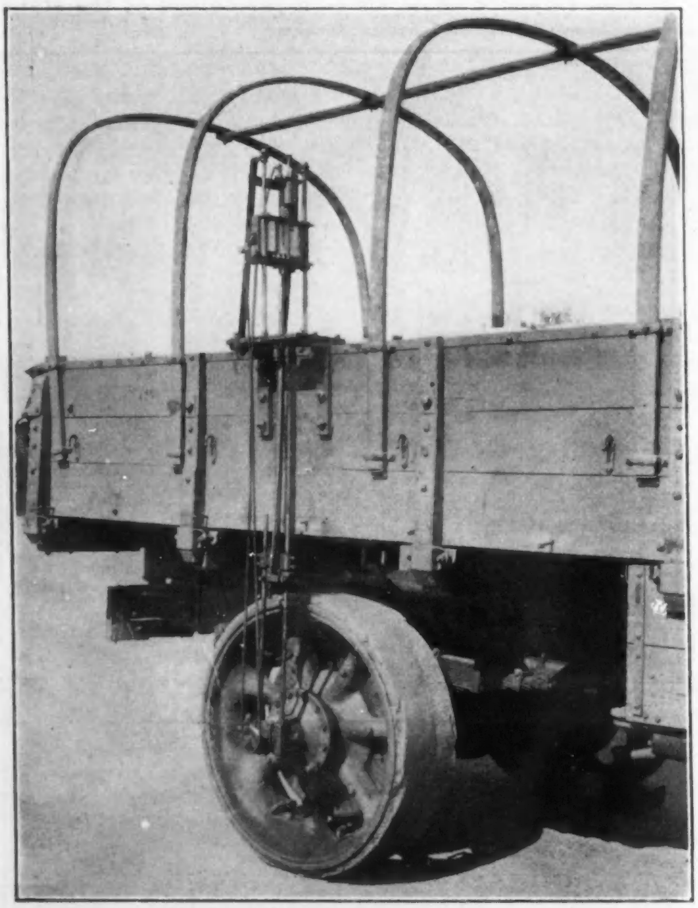

FIG. 2—TYPICAL TEST-TRUCK EQUIPPED WITH MEASURING APPARATUS SPECIALLY DESIGNED, DEVELOPED AND CALIBRATED FOR THESE TESTS
The Trucks Varied in Size from 1 to 5 Tons and Were Equipped with Tires of Various Sizes and Types

OBSTRUCTIONS ON TEST ROAD

Obstruction	Type	Width, In.	Height, In.	Symbol
1	Inclined Plane	30	13/16 = 0.81	•
2	Inclined Plane	30	1 15/16 = 1.94	○
3	Rectangular Block	3	1 1/8 = 1.12	•
4	Rectangular Block	3	9/16 = 0.56	○
5	Rounded Block	3	1 1/2 = 1.50	•
6	Rounded Block	3	3/4 = 0.75	○
7	Inclined Plane	30	1 1/2 = 1.50	×
8	Rectangular Block	3	7/8 = 0.88	×

FIG. 3—THE ARTIFICIAL OBSTRUCTIONS
These Varied in Height and Type as Shown

The impact road-reaction of a motor-truck depends, in general, on the four major variables: wheel load, truck speed, tire equipment, and road roughness. The effects of other variables, such as the ratio of the unsprung to the sprung weight, truck-spring flexibility, and the like, are also felt, but manufacturing and operating conditions are generally such that the effect of these latter variables, so far as the road is concerned, is not of major importance.

IMPACT COMPONENTS

The impact reaction is separable into two distinct elements, which are the two forces acting simultaneously and cumulatively on the pavement. One is the force represented by the net truck-spring pressure at the instant of impact, its magnitude varying with the truck-spring deflection. The other is the force required to change the vertical velocity of the unsprung truck-weight, that is, the parts below and not supported by the truck spring as the wheel is vertically accelerated or decelerated by the pavement. The vertical impact-reaction thus separated into its components, caused by the sprung and the unsprung parts for a typical test-condition, is shown in Fig. 6. It has been found that the most severe impacts occur either at the shock on striking an obstruction, or at the first rebound or drop after the obstruction has been passed. It is also generally true that the unsprung component of the road reaction is the major quantity, and, so long as the unsprung truck-weight is decelerated, or accelerated, at all, it is likely to be the deciding factor in the total road-reaction regardless of the compression of the truck spring. The influence of the truck spring is felt, however, as shown in this illustration and under certain conditions, particularly at low speeds and with pneumatic tire-equipment; the lessening of the sprung component due to the opening of the truck spring may be sufficient to cause the total vertical impact-reaction to be less than if the truck had been standing on the road. At normal operating-speeds, however, the unsprung component constitutes most of the impact reaction, and, other conditions remaining constant, this unsprung component varies inversely with the cushioning qualities possessed by the tire equipments. It is again noted that pneumatic equipment did not cause reactions as great as twice the static load. The reaction of the new solid-tire at customary speeds is shown to be about five times the static load for this test-condition.

In this illustration, it is also apparent that, for the test condition involving new solid-tires, the unsprung component comprised about 90 per cent of the total road-reaction at all ordinary operating-speeds. With the sprung component, then, comprising the other 10 per cent of the total reaction, it becomes evident that cushioning media above the truck spring proper can have only a very slight influence on the road reaction, although the body motion might be very appreciably affected. It is the cushioning material below the truck springs that governs the road reaction. The riding-qualities of the chassis may also be influenced by cushioning media in the seats or at various other points of suspension above the springs. The use of spring snubbers would influence the road reaction principally as the vertical velocity of the axle was affected, although they unquestionably greatly influence the riding-qualities of the chassis.

When the vehicle is standing still, the road reaction is the static wheel-load, but, with the truck in motion, this condition no longer obtains. Some conception of the nature of the phenomena of motor-truck impact may be had by considering the behavior of two imaginary trucks, the first, a truck on which practically the entire wheel-load is derived from the unsprung weight and the body

Fig. 5—The Effect of the Height of Artificial Obstructions on the Impact Forces

Pneumatic Tires Did Not Allow an Impact Force Greater Than Twice the Static Load, at Least up to 2 In. in the Height of the Inclined Plane, While the Same Truck, Load and Speed Developed an Impact Reaction of Twice the Static Load, When Worn-Out Solid Tires Passed over an Inclined Plane Only 0.15 In. in Height

pavement under the combined influences of the truck spring and gravity, and would be decelerated through the medium of whatever cushioning materials were in the tires.

The difference in the actions of these two imaginary trucks lies in the inertia of the respective unsprung

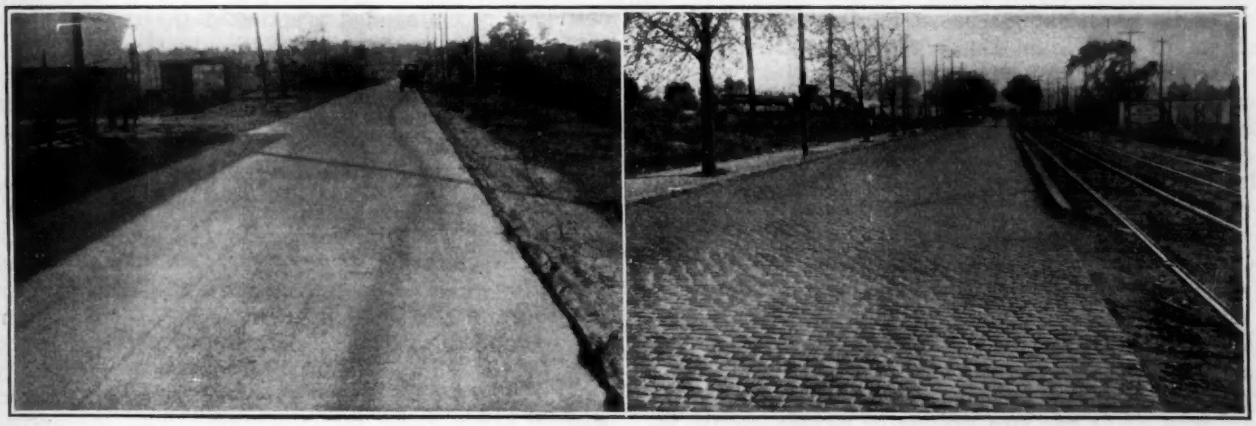

Fig. 4—Two Views of the Test Highway

At the Left Is Shown a Section of Smooth Concrete Pavement; at the Right, One of Rough Stone Blocks

is but a skeleton supported by comparatively light truck-springs. If, under such conditions, the tires are grossly overloaded, it will readily be seen that, as long as there is any appreciable cushioning material present in the tires, the excessive unsprung load directly on the tires would cause them, under all but the most extreme conditions of speed and road roughness, to remain in constant intimate contact with the road. Comparatively slight obstructions would be embedded in the tire under the influence of the great unsprung load, and there would be practically no difference between the cushioning qualities or springiness of various tires so long as they were able to carry the load at all.

Consider, now, a second imaginary truck at the other extreme, in which the unsprung weight is a mere skeleton and the sprung weight, supported by adequate springs, is the principal load. An excessive wheel-load, under these conditions, would not hold the tires so closely in contact with the road, for the relatively light wheel could readily be kicked upward as obstructions were encountered on the road. The measure of this kick would be determined by the amount and the quality of the cushioning material in the tire. Having been raised into the air, the wheel would then be returned to the

weights. The inertia of the heavy unsprung-weight of the first truck caused the tires to absorb road roughnesses because of the short time-interval in passing a given point, if the truck were moving at any speed at

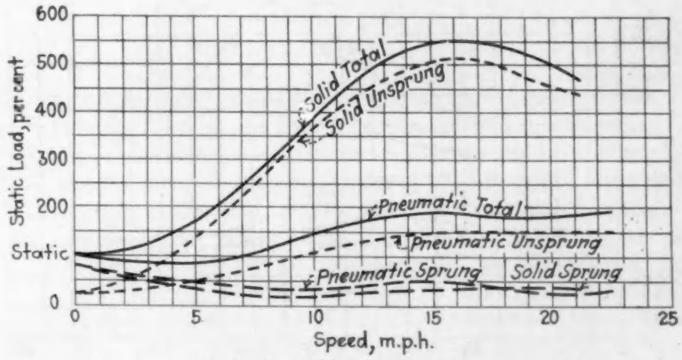

Fig. 6—The Components of Impact Reactions

The Impact Reaction Is Separable into Two Distinct Elements, Namely, the Two Forces Acting Simultaneously and Cumulatively on the Pavement. The First Is Represented by the Net Truck-Spring Pressure at the Instant of Impact, Its Magnitude Varying with the Truck-Spring Deflection. The Second Is the Force Required to Change the Vertical Velocity of the Unsprung Truck-Weight as the Wheel Is Accelerated or Decelerated by the Pavement

all. The lack of inertia in the second case allowed the unsprung weight to bob up and down along the road in response to the least roughness. It is true that a heavy sprung-weight involves a heavy spring-pressure that would resist the upward movement of the axle and would have a tendency to hold the tire against the pavement, but the sprung weight would nevertheless still be floating and some opportunity would be afforded for the axle to move up and down. If practically all the weight were unsprung, then there would be only the cushioning material of the tire to absorb the impact. Under service conditions, a truck is a fortunate medium between the two imaginary extremes just described, but certain test-conditions have been created in which the effects described will be to some degree perceptible.

Influence of Load on Impact

In Fig. 7 are shown the effect of truck capacity on impact reactions and the influence of wheel load on pneumatic and on new solid-tire equipments. The rated truck-capacities in terms of tire load are indicated; and it will be seen that, with one exception, the trucks were apparently over-tired when equipped with sizes ordinarily specified as standard equipment, the trucks being at rated capacity-loads when the tires carried about 90 per cent of their capacity-loads. It will also be noted that excessive over-loading has a tendency to eliminate the effects of individual truck characteristics because, under extreme sprung-loads, the truck springs are not allowed to function in a normal manner. As indicated in this figure, the 2, 3 and 5-ton trucks are about to seek common curves to represent their behavior as the load increases for a given type of tire equipment. This does not mean that the reactions in pounds for each of these trucks are identical, but that the relative effects, expressed as percentages of the static loads, are approximately the same. As indicated in the earlier discussion, these curves demonstrate that excessive total-loads have a tendency to reduce the differences between the cushioning qualities of tire equipment so long as the tires are able to carry the loads at all. A logical extrapolation of the curves, or of the two groups of curves, would indicate that, if the loads were increased to $2\frac{1}{2}$ or 3 times the rated carrying-capacity loads of the tires, the increase over the static load would become negligible for the given speed and obstruction conditions and for ranges of cushioning material between those of the pneumatic and the new solid-tire equipments.

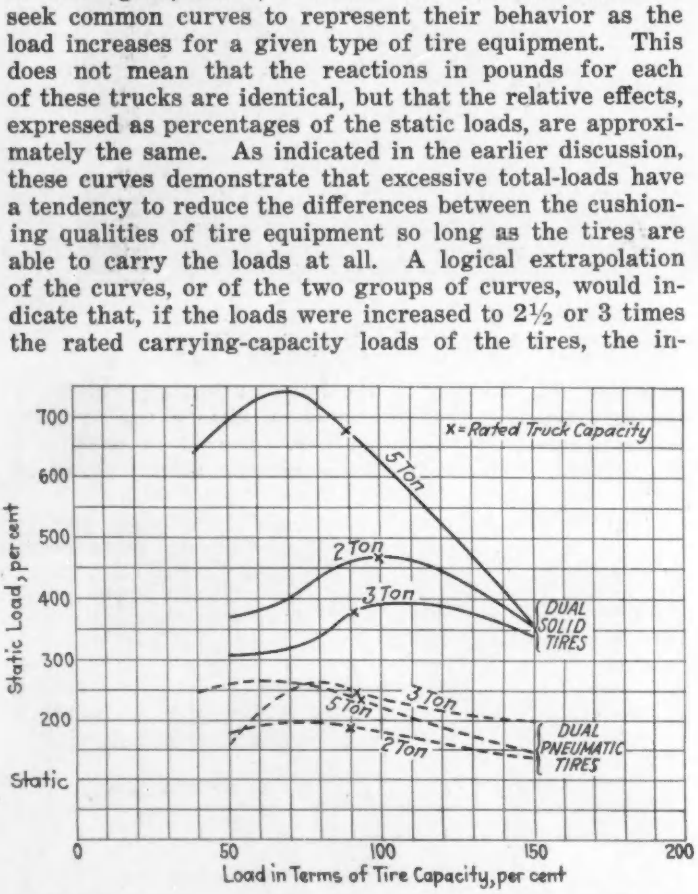

Fig. 7—The Influence of Wheel Loads on Impact Forces
The Rated Truck-Capacities in Terms of Tire Load Are Indicated. With One Exception, the Trucks Were Apparently Over-Tired When Equipped with Sizes Ordinarily Specified as Standard Equipment. The Curves Indicate That the 2, 3 and 5-Ton Trucks Are About To Seek Common Curves To Represent Their Behavior as the Load Increases for a Given Type of Tire Equipment

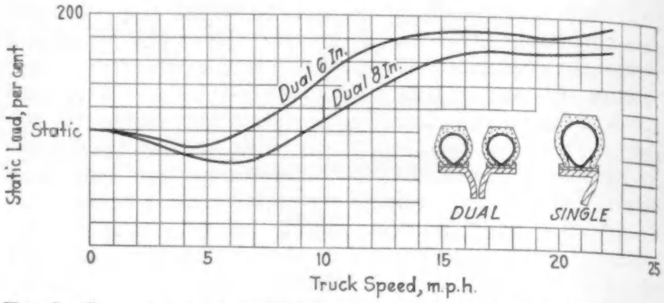

Fig. 8—Comparison of the Reactions of Single and Dual Mountings and the Influence of Truck Speed on Impact Forces
Both Mountings Have Approximately the Same Load-Carrying Capacity and Were the Standard Recommended Practice at the Time of the Tests. It Is Evident That the Dual Mounting Caused Heavier Impact-Reactions Than the Single Mounting Under the Same Test-Conditions

Influence of Tires on Impact

A comparison of the reactions of two smaller tires mounted dually with those of one larger tire mounted singly is shown in Fig. 8. Both mountings have approximately the same load-carrying capacity and were the standard recommended practice at the time of the tests. It is evident at once that the dual mounting caused heavier impact-reactions than the single mounting for the same test-conditions. The reason for this difference is found in the cross-sections of the cushioning materials and has been borne out by similar tests with solid tires on a 5-ton truck. The single tire offers a relatively thicker and narrower cushioning-medium than the dual mounting of the same material. Consequently, acceleration or deceleration of the truck wheel may be accomplished by the dual mounting with less tire-compression, and therefore in a shorter interval of time, than the single mounting. The acceleration or deceleration occurring in the shorter time-interval must necessarily be greater to produce the required change in vertical velocity for a given test-condition. The acceleration of the unsprung weight being greater, it follows that the unsprung component of the road reaction is greater, because it is the product of the acceleration and the mass of the unsprung weight. Given two otherwise equal cushioning media, the one whose materials and construction are such that the necessary change in velocity can be accomplished in the longer time-interval will cause the lower impact-reaction, because the acceleration, or deceleration, will be less.

A somewhat analogous condition is indicated in the comparison between overloaded versus oversized tire-equipments, shown in Fig. 9. The reason for the oversized tires' causing heavier reactions than the overloaded tires is again found in the relative dimensions of the two sizes of tire of each type. If the tire cross-sections were superimposed, a marked difference in width would be noticed, and practically no difference in height. The narrower tire would naturally be more easily deformed, and, because of this, could effect the necessary change in velocity by being compressed a greater distance during a longer time-interval than the wider tire would be during a relatively short compression-distance. It is interesting also to note, in connection with this figure, that the impact force is only about 15 per cent in excess of the static load for the rated size of under-inflated pneumatic tires, and nearly 700 per cent in excess for the worn-out solid-tires, which were oversized

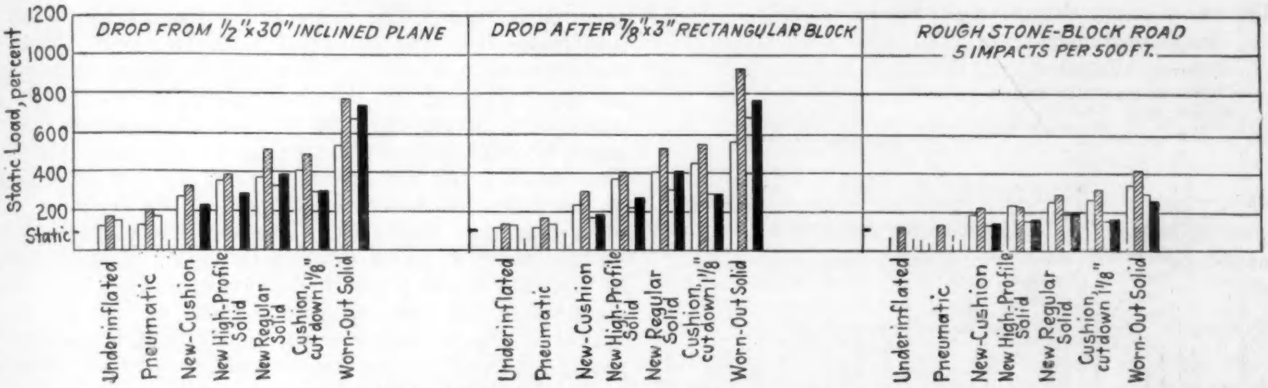

FIG. 9—COMPARISON OF OVERLOADED AND OVERSIZED TIRE-EQUIPMENTS

The Reason for the Oversized Tires Causing Heavier Reactions Than the Overloaded Tires Is To Be Found in the Relative Dimensions of the Two Sizes of Tire of Each Type. If the Tire Cross-Sections Were Superimposed, a Marked Difference in Width Would Be Noticed, and Practically No Difference in Height. The Narrower Tire Is Naturally More Easily Deformed, and Consequently Effects the Necessary Change in Velocity by Being Compressed a Greater Distance During a Longer Time-Interval, Than Is the Wider Tire During a Relatively Short Compression-Distance

equipment for the same truck at approximately the same load.

Influence of Road Roughness on Impact

A comparison of the results obtained from typical tests on smooth and rough highway sections will be found in Fig. 10. The upper chart of Fig. 10 shows the number of times the truck wheel struck the 500-ft. length of rough stone-block road with a blow of a given magnitude, for the four types of tire compared. The lower chart shows similar data for a smooth concrete pavement, the trucks, loads, speeds, and tire equipments being respectively the same. Referring to the two charts, we find, by way of example, that, loaded to tire capacity and operated at 12 m.p.h., the 2-ton truck on pneumatic tires struck the smooth concrete pavement 50 times per 500 ft. traveled with an impact force only 5 per cent in excess of the static load, but the worn-out solid-tires struck the same road 50 times per 500 ft. with an impact force 45 per cent in excess of the static load. Again, 50 impacts on the rough stone-block road occurred with a magnitude of 40 per cent in excess of the static load for pneumatic equipment and 270 per cent in excess of

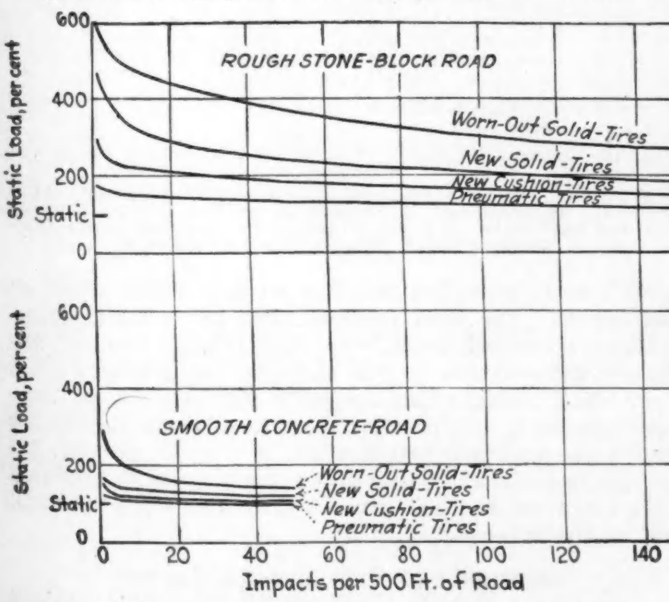

FIG. 10—COMPARATIVE IMPACT REACTIONS ON HIGHWAYS OF DIFFERENT TYPES

The Upper Chart Shows the Number of Times the Truck Wheel Struck the 500-Ft. Length of Rough Stone-Block Pavement a Blow of Given Magnitude for the Four Types of Tire That Are Compared; the Lower Chart Shows Corresponding Data for a Smooth Concrete Pavement, the Truck, Load, Speed and Tire Equipment Being Respectively the Same.

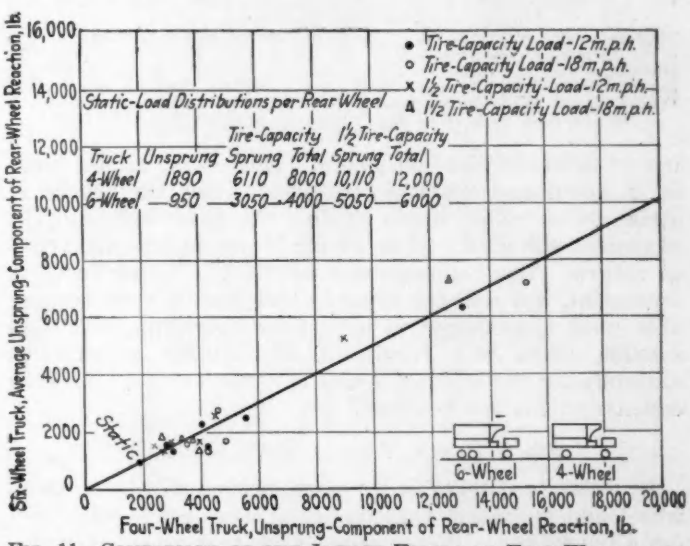

FIG. 11—COMPARISON OF THE IMPACT FORCES OF FOUR-WHEEL AND SIX-WHEEL TRUCKS

The Tests Were Made with Two 5-Ton Trucks That Differed Only in the Rear-Wheel Arrangement. The Curve Shows That the Unsprung Component of the Impact Reaction of the Six-Wheel Truck Is One-Half the Reaction Caused by the Four-Wheel Truck Under Otherwise Equivalent Test-Conditions.

the static load for worn-out solid-tire equipment. This may be generally expressed by remembering that good tire-equipment will make even a rough road seem to be reasonably smooth, and that poor tire-equipment will make even a smooth road seem to be unreasonably rough. With pneumatic tires, it is very difficult to cause road reactions of double the static load, and most of them are much less than that amount; with worn-out solid-tires, it is very easy to cause a reaction of ten times the static load, and that amount is quite often exceeded.

It is not likely that any thoughtful truck-owner would care to see his 3-ton trucks suspended in the air and undergoing treatment from a trip-hammer arranged beneath to strike 35-ton blows continually against the tires, and with occasional blows even more severe. There would be an economically sound reason for the truck-owner's removing the damaging trip-hammer or, if this could not be done, for tempering the severity of the blows struck by it as soon as possible. The above is not an idle example. The equivalent effect may easily occur if he allows his truck to be operated on the highways with worn-out tire-equipment. Aside from damaging a good road, or making a bad road worse, not only for himself but for others who have an equal right to use it, he is hammering out the life of his trucks by the

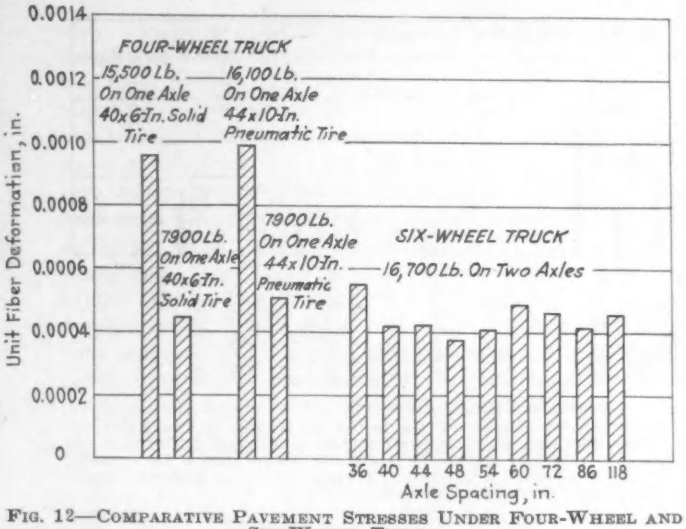

FIG. 12—COMPARATIVE PAVEMENT STRESSES UNDER FOUR-WHEEL AND SIX-WHEEL TRUCKS

This Is a Study of the Relative Fiber Deformation Produced in a 6-In. Concrete Pavement-Slab by Four and Six-Wheel Vehicles Having, First, the Same Gross-Loads and, Second, the Same Wheel-Loads. The Data Indicate That, for a Given Gross-Load, a Six-Wheel Truck Will Cause About One-Half the Tensile Deformation in the Slab That Will Be Caused by a Four-Wheel Truck

use of worn-out tire-equipment. For every action there is an equal and opposite reaction. Allow the trucks to strike 30 or 50-ton blows against the pavement, and the pavement will strike 30 or 50-ton blows against the truck in return. The highway will not be the better for this treatment, but will the truck? The use of even reasonably good tire-equipment on trucks operating with reasonable loads will result in less public expense in maintaining the highways and less operating or up-keep expense to the truck-owner.

SIX WHEELS VERSUS FOUR WHEELS

In order to determine the comparative effects of four-wheel and six-wheel vehicles, tests were made with two 5-ton trucks that differed only in the rear-wheel arrangement. Some of the results of this investigation are shown in Fig. 11. One of these trucks was of the standard four-wheel type equipped at the rear with dual

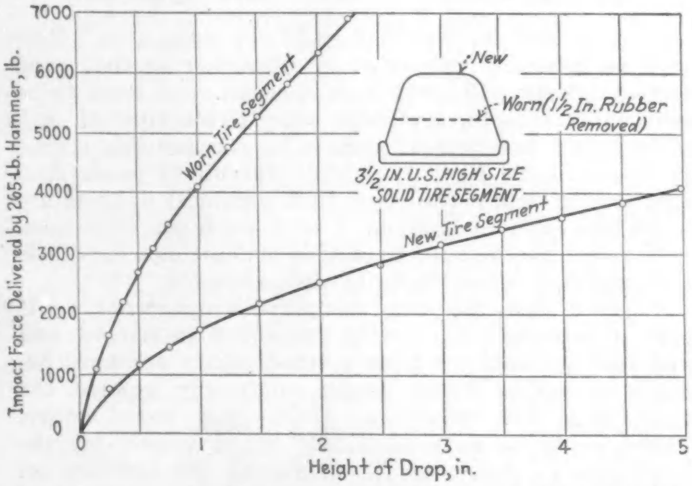

FIG. 13—INFLUENCE OF THE DIFFERENCE OF THE HEIGHT OF THE RUBBER, CAUSED BY TIRE WEAR, ON THE IMPACT FORCE

These Curves Were Obtained from the Data of a Series of Tests in Which the Relation Between the Static and the Dynamic Strains in Concrete Beams Was the Primary Object. A Hammer Was Equipped with Tire Segments and Arranged To Drop on an Anvil. The Impact Reaction of a Solid Tire Worn to About 50 Per Cent of Its Original Over-all Height Is Shown To Be About 250 Per Cent of the Corresponding Reaction of That Tire When New. This Relation Has Been Substantiated for Motor-Truck Tires in Actual Service during the Course of an Extended Series of Tests on the Effect of Tire Height on Motor-Truck Impact-Reactions

pneumatic tires. The other truck was of the same size and make but was equipped with two rear axles that carried singly mounted tires of the same cross-section as those carried by the four-wheel truck. Both rear axles were driven through tandem differentials, the distance between axle centers being slightly more than 4 ft. The usual truck spring was inverted, each end resting on one axle and the center supporting the body by means of a trunnion fastening. The six-wheel truck carried on its two rear axles total loads equal to those carried by the four-wheel truck on its one rear axle. The figure shows that the unsprung component of the impact reaction of the six-wheel truck approximated one-half the reaction caused by the four-wheel truck under otherwise equivalent test-conditions.

A study was made of the relative fiber deformations produced in a 6-in. concrete pavement-slab by four and by six-wheel vehicles, having, first, the same gross-loads, and, second, the same wheel-loads. The results are represented graphically in Fig. 12. The difference in the four-wheel trucks was only in the areas of contact between the tire and the pavement due to the type of tire;

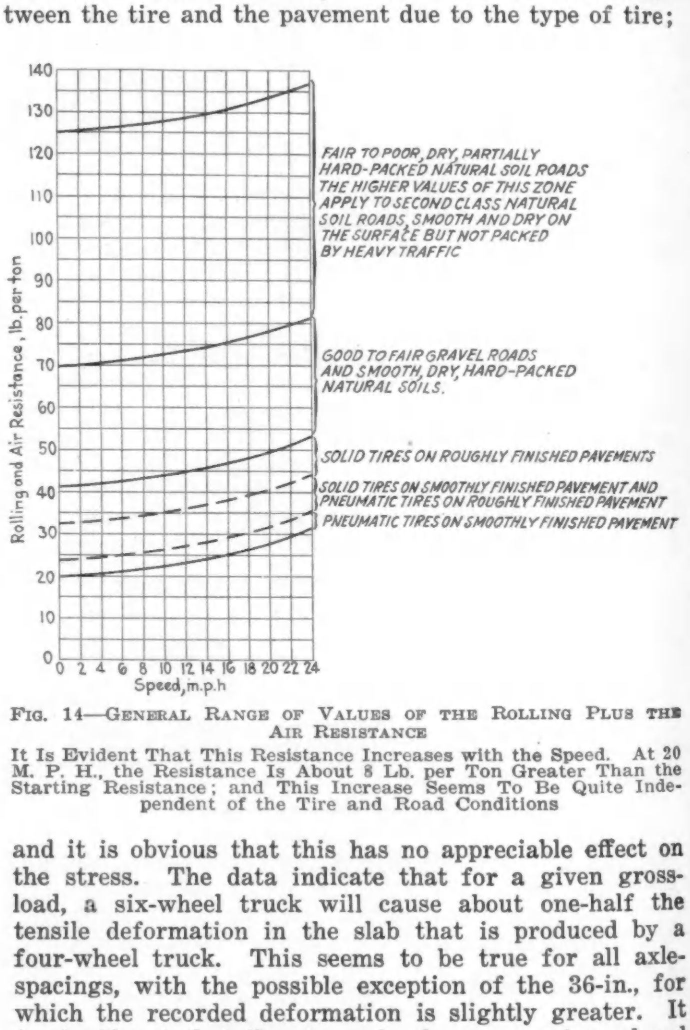

FIG. 14—GENERAL RANGE OF VALUES OF THE ROLLING PLUS THE AIR RESISTANCE

It Is Evident That This Resistance Increases with the Speed. At 20 M. P. H., the Resistance Is About 8 Lb. per Ton Greater Than the Starting Resistance; and This Increase Seems To Be Quite Independent of the Tire and Road Conditions

and it is obvious that this has no appreciable effect on the stress. The data indicate that for a given gross-load, a six-wheel truck will cause about one-half the tensile deformation in the slab that is produced by a four-wheel truck. This seems to be true for all axle-spacings, with the possible exception of the 36-in., for which the recorded deformation is slightly greater. It is significant that the stress in the pavement produced by a six-wheel truck is a function of the wheel-load and not of the axle-spacing.

INFLUENCE OF TIRE WEAR ON IMPACT

In Fig. 13 is shown the effect of tire wear on impact force. These curves were obtained from the data of a series of tests in which the relation between the static and the impact strains in concrete beams was the primary object. A hammer was equipped with tire segments and

arranged to drop on an anvil. The impact reaction of a solid tire worn to about 50 per cent of its original over-all height is shown to be about 250 per cent of the corresponding reaction of that tire when new. This relation has been substantiated for motor-truck tires in actual service during the course of an extended series of tests on the effect of tire height on motor-truck impact-reactions, the data on which have not yet been released by the Joint Committee.

An interesting side-light was brought out in the impact tests that emphasizes the importance of the use of tire equipments that are circumferentially uniform in cross-section. During the tests a certain type of new tire, which had a non-skid tread now obsolete, was used on a truck as dual equipment. The tires were placed on the wheel with the tread designs opposite, and then with the designs staggered. The markings on the tires were unusually deep and by varying the mountings as above an exceptional variation in cross-sectional rubber was obtained. This change in mounting was of itself sufficient to change the impact reaction from 3600 to 1200 lb. at each repetition of the tread design, or about 8 in., along a smooth concrete road. The reaction caused by no other disturbance than the variation in the cross-section of the rubber was three times as great for the worse condition as it was for the better condition, or when the tread designs were staggered.

Rolling Resistance

In Fig. 14 are shown some results of the measurement of rolling resistances. It is evident that this resistance increases with increase in speed. At 20 m.p.h., the resistance is about 8 lb. per ton greater than the starting resistance; and this increase seems to be quite independent of the tire or road conditions. The resistance of solid tires is more than 50 per cent greater than that of pneumatic tires for a given road; and the resistance of a rough pavement is from one-third to one-sixth greater than that of a smooth pavement. An expected rise in rolling resistance is found on non-rigid pavements; on hard natural soils the value of this resistance is more than 125 lb. per ton, or one-sixteenth of the load carried.

TABLE 1—SHOWING AVERAGE ROLLING-RESISTANCE AND RELATIVE FUEL-CONSUMPTION

Type and Condition of Roadway Surface	Average Values, Rolling Plus Air Resistance				Relative Fuel Consumption, with that on Surface for which R = 30 Lb. per Ton Taken as Unity			
	Solid Tires,	Pneumatic Tires			Solid Tires,	Pneumatic Tires		
	10 M.P.H.	15 M.P.H.	25 M.P.H.	35 M.P.H.	10 M.P.H.	15 M.P.H.	25 M.P.H.	35 M.P.H.
Portland cement concrete, best newly finished	30	22	27	35	1.00	0.89	0.96	1.07
Portland cement concrete, rough due to poor work	36	30	35	42	1.08	1.00	1.07	1.16
Portland cement concrete, average good condition	32	27	32	39	1.02	0.96	1.02	1.12
Asphaltic concrete, coarse graded type, average yearly temperature, best	30	25	30	37	1.00	0.93	1.00	1.09
Asphaltic concrete, coarse graded type, average yearly temperature, average	33	27	32	39	1.04	0.96	1.02	1.12
Sheet asphalt, at average yearly temperature, best	28	23	28	35	0.97	0.91	0.97	1.07
Sheet asphalt, at average yearly temperature, average	36	30	35	42	1.08	1.00	1.07	1.16
Bituminous-filled brick, average, no filler on surface	30	26	31	38	1.00	0.95	1.01	1.11
Grout-filled brick, average	37	30	38	45	1.09	1.00	1.11	1.20
Wood block, bare of filler, average uniform surface	35	30	34	40	1.07	1.00	1.05	1.13
Gravel, best, clay-bound	40	35	40	47	1.13	1.07	1.13	1.23
Gravel, fair to poor, rough spots, some loose material	55	50	55	62	1.33	1.27	1.33	1.42
Gravel, poorest condition, rough and many loose pieces	60	55	60	65	1.40	1.33	1.40	1.47
Gravel, Iowa, yearly average, approximated	50	45	50	57	1.27	1.20	1.27	1.36
Natural soil, good, well graded and patrol maintained	45	35	40	47	1.20	1.07	1.13	1.23
Natural soil, soft, or slightly "spongy"	70	70	75	80	1.54	1.53	1.60	1.67
Natural soil, Iowa, yearly average, approximated	55	45	50	58	1.33	1.20	1.27	1.37
Snow, 2 in. thick, well packed	55	50	70	..	1.33	1.27	1.53	....
Snow, about 4 in. thick, slightly packed	75	70	..	..	1.60	1.53	....	....
Snow, about 4 in. thick, slightly packed, chains on wheels	75	..	..	..	1.60	....	....	....
Average for best paved surfaces, concrete, asphalt, brick and wood block	30	22	27	37	1.00	0.89	0.96	1.09
Average for partly worn pavements, that is, in fair average condition	35	30	35	42	1.07	1.00	1.07	1.16
Yearly average for best gravel of type used on trunk lines	45	40	45	55	1.20	1.12	1.20	1.33
Yearly average for ordinary gravel found on secondary roads	55	50	55	65	1.33	1.27	1.33	1.47
Yearly average for well-maintained county system, earth roads	65	60	63	75	1.47	1.40	1.44	1.60
Yearly average for well-maintained primary system, earth roads	55	50	53	65	1.33	1.27	1.31	1.47

TABLE 2—VALUES OF COEFFICIENT OF FRICTION AT SPEEDS OF FROM 3 TO 5 M.P.H. WHEN SLIDING IS IN THE LINE OF MOTION

Type of Surface	Condition of Surface	Size and Type of Tires; Size, In.; Pressure, Lb. per Sq. In.	Weight on Rear Wheels, Lb.	Start of Sliding: Force Required to Slide Wheels, Lb.	Start of Sliding: Coefficient of Friction	Uniform Sliding: Force Required to Slide Wheels, Lb.	Uniform Sliding: Coefficient of Friction
		Pneumatic Tires					
Smooth Portland Cement Concrete	Dry	36x6-in. Goodrich, De Luxe Cords (new); 90-lb. tire-pressure	2,700	1,854	0.687	1,644	0.609
	Dry		3,270	2,210	0.676	1,925	0.590
	Wet		2,700	1,526	0.565	1,396	0.517
	Dry	33x4-in. Blackhawk, Non-Skid Tread (new); 65-lb. tire-pressure. (This series at speed 10 to 12 M.P.H.)	1,470	1,256	0.854	1,140	0.775
	Dry		1,940	1,518	0.783	1,434	0.739
	Wet		1,470	921	0.627	804	0.547
	Dry		1,940	Not Determined		1,215	0.627
Wood Block	Dry	36x6-in. Goodrich, De Luxe Cords (new); 90-lb. tire-pressure	2,700	1,817	0.673	1,447	0.536
	Dry		3,270	1,988	0.602	1,758	0.537
	Wet		2,700	1,067	0.395	737	0.273
	Dry	33x4-in. Blackhawk, Non-Skid Tread (new); 65-lb. tire-pressure	1,470	1,140	0.776	1,051	0.715
	Dry		1,940	1,352	0.697	1,244	0.641
	Wet		1,470	576	0.392	445	0.303
Smooth Bitulithic	Dry	36x6-in. Goodrich, De Luxe Cords (new); 90-lb. tire-pressure	2,700	1,810	0.670	1,690	0.626
	Dry		2,168	2,168	0.663	2,003	0.613
	Wet		1,420	1,420	0.526	1,300	0.481
	Dry	33x4-in. Blackhawk, Non-Skid Tread (new); 65-lb. tire-pressure. (Minimum average of 4 runs)	1,470	1,091	0.743	1,001	0.682
	Dry		1,940	1,467	0.756	1,348	0.695
	Wet		1,470	922	0.627	797	0.542
	Wet		1,470	Not Noticeable		720	0.490
Hard-Packed Snow on Pavement	Frozen	33x4-in. Blackhawk, Non-Skid Tread (new)	1,940	762	0.393	405	0.209
	Icy		1,940	524	0.270	347	0.179
	Thawing	40x8-in. U. S. Cords, Nobby Tread	4,500	1,085	0.241	689	0.153
Smooth Portland Cement Concrete	Dry	36x4-in. U. S. Regular, Smooth Tread	4,420	2,652	0.600	2,024	0.458
	Dry		3,560	2,132	0.599	1,634	0.459
	Wet		4,420	1,540	0.349	1,385	0.311
	Dry	36x6-in. U. S. Standard, Smooth Tread	4,630	2,894	0.625	2,468	0.533
	Dry		3,640	2,515	0.691	2,060	0.566
	Wet		4,630	2,259	0.488	1,889	0.408
		Solid Tires					
Smooth Bitulithic	Dry	36x4-in. U. S. Regular, Smooth Tread	4,420	2,589	0.585	2,214	0.501
	Dry		3,560	2,068	0.581	1,727	0.485
	Wet		4,440	1,676	0.374	1,481	0.330
	Dry	36x6-in. U. S. Standard, Smooth Tread	4,630	2,718	0.587	2,449	0.529
	Dry		3,640	2,399	0.659	2,060	0.566
	Wet		4,630	2,093	0.452	1,815	0.392
Wood Block	Dry	36x4-in. U. S. Regular, Smooth Tread	4,420	2,524	0.571	2,064	0.467
	Dry		3,560	2,118	0.595	1,677	0.471
	Wet		4,440	1,140	0.238	1,000	0.225
	Dry	36x6-in. U. S. Standard, Smooth Tread	4,630	2,685	0.580	2,343	0.506
	Dry		5,830	3,247	0.557	2,950	0.506
	Dry		3,640	2,166	0.595	1,933	0.531
	Wet		4,630	1,384	0.299	1,158	0.250
Hard-Packed Snow on Pavement	Melting	36x4-in. U. S. Regular, Smooth Tread	4,420	769	0.174	548	0.124
	Frozen	36x6-in. U. S. Standard, Smooth Tread	4,630	935	0.202	732	0.158
	Melting (Rain)		4,630	931	0.201	736	0.159
Ice and Sleet	Smooth and Freezing	36x6-in. U. S. Standard, Smooth Tread	4,630	394	0.085	319	0.069
	Roughened by Traffic WeedChains	36x6-in. U. S. Standard, Smooth Tread	4,630	727	0.157	468	0.101

TABLE 3—VALUES OF COEFFICIENT OF FRICTION WHEN SLIDING IS NORMAL TO PATH OF VEHICLE

Run No.	Type of Surface	Condition of Surface	Size and Type of Tires	Weight on Rear Wheels (S)	Total Starting Force, Lb.	f^6 Per Pound of Weight, Lb.
			Pneumatic Tires			
64	Smooth concrete	Dry	33x4-in. Federal and Royal Cord	1,870	600	0.387
65	Good asphalt	Dry	33x4-in. Federal and Royal Cord	1,870	495	0.318
66	Fair wood block	Dry	33x4-in. Federal and Royal Cord	1,870	380	0.245
67	Gravel	Spongy	33x4-in. Federal and Royal Cord	1,870	405	0.261
68	Natural soil	Spongy	33x4-in. Federal and Royal Cord	1,870	465	0.300
69	Smooth concrete	Dry	36x6-in. Goodrich De Luxe Cord	2,770	885	0.401
70	Good bitulithic	Dry	36x6-in. Goodrich De Luxe Cord	2,770	915	0.415
71	Wood block	Dry	36x6-in. Goodrich De Luxe Cord	2,770	950	0.431
72	Good gravel	Dry	36x6-in. Goodrich De Luxe Cord	2,770	760	0.344
73	Carpet coat	Dry	36x6-in. Goodrich De Luxe Cord	2,770	920	0.417
74	Loose sandy natural soil	Spongy	36x6-in. Goodrich De Luxe Cord	2,770	700	0.318
			Solid Tires			
75	Smooth concrete	Dry	36x6-in. badly worn	2,560	650	0.324
76	Good bitulithic	Dry	36x6-in. badly worn	2,560	605	0.301
77	Fair wood block	Dry	36x6-in. badly worn	2,560	670	0.334
78	Natural soil (sandy)	Spongy	36x6-in. badly worn	2,560	540	0.269
79	Gravel	Dry	36x6-in. badly worn	2,560	600	0.299
80	Carpet coat	Dry	36x6-in. badly worn	2,560	700	0.348
81	Gravel (good)	Dry	36x6-in. dual-tread	4,360	1,135	0.290
82	Carpet coat	Dry	36x6-in. dual-tread	4,360	1,235	0.312
83	Natural soil (sandy)	Spongy	36x6-in. dual-tread	4,360	1,050	0.266
84	Good concrete	Dry	36x6-in. dual-tread	4,360	1,285	0.325
85	Bitulithic (good)	Dry	36x6-in. dual-tread	4,360	1,110	0.281
86	Fair wood block	Dry	36x6-in. dual-tread	4,360	1,330	0.336

f^6 equals the total force producing sliding in pounds divided by the weight of the sliding wheels in pounds.

Gasoline Consumption

In Table 1 are given the average values of the rolling resistance plus the air resistance and the relative fuel-consumption for the extremes in new tire-equipments and for a wide variety of highway conditions. The gasoline consumption required for a given load on pneumatic tires at 25 m.p.h. is approximately the same as would be required for the same load on solid tires at only 10 m.p.h., regardless of the road condition. Interpreting this table in the light of gasoline consumption alone, it appears that from three-tenths to six-tenths of the cost of the gasoline used could be economically spent in snow-removal, and that about one-tenth of the cost of gasoline to be used could be profitably spent in securing and maintaining a smoothly finished pavement rather than one having a rough finish.

Skidding

Tables 2 and 3 show values of the coefficients of friction for many tire and pavement conditions. They are included, in order to give truck operators an idea of the relative safety of operation of trucks over highways of varying degrees of slipperiness. Forward or sidewise skidding occurs when the force tending to produce slipping equals or exceeds the proportion of the wheel load indicated by the coefficient of friction, *f*.

THE DISCUSSION

A. L. Schoff:—With regard to the question whether the rules of some State highway commissions were not questionable in requiring larger tires to support larger loads, in view of the fact that the Bureau of Public Roads tests show higher impacts with oversized tires than with overloaded tires, it seems to me that the results of the Bureau of Public Roads tests as published so far are decidedly misleading in that they have so many times set forth their findings that impact is lowered by using a tire of smaller width.

The total impact, no doubt, is lowered, because the tire is overloaded and deformed beyond what is good practice, but, in view of the fact that this total impact, though lowered, is confined to a smaller area of the road, it is probable that the total damaging effect to the road is greater than when the larger and correct tire is used.

Unless this phase of these reports is cleared up, on the basis of what has so far been published, the public will certainly get the impression that small tires decrease the impact and therefore should be the proper equipment; whereas, of course, this cannot possibly be true and will lead only to a misunderstanding of the reasons that have prompted so many State highway departments to limit the loads carried by tires of certain sizes.

J. A. Buchanan:—As Mr. Schoff states, the total vertical impact-reaction occurring with a narrower tire is less than that occurring with a wider tire of the same height and type but under otherwise equivalent test-conditions, and provided that the smaller tire is not compressed to the point where the steel tire-flanges strike the road. It is also true that the area and width of contact at a given load are both less in the case of the narrower tire. A truck wheel generally damages a roadway either by impact or by rutting. In impact, it is the total load which is important. In rutting, it is the load intensity which is important. It would appear that, on "rigid" pavement-surfaces, the narrower the tire the better, while on "non-rigid" pavement-surfaces the opposite is true.

Discussion of Papers at the Annual Meeting

THE discussion following the presentation of two of the papers at the Annual Meeting of the Society that was held at Detroit in January is printed herewith. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication. For the convenience of the members a brief abstract of each paper precedes the discussion so that members who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the February 1927 issue of THE JOURNAL can do so easily.

Supplementing his written paper Mr. Phillips interpolated some remarks in connection with exhibits of chromium-plated objects and the projection of lantern slides. These follow the abstract and precede the discussion proper.

PURPOSES, METHODS AND RESULTS OF CHROMIUM-PLATING

BY W. N. PHILLIPS[1]

ABSTRACT

CHROMIUM-PLATING for decorative effect has been used for considerably more than a year on the Oldsmobile radiators and bumper-bars and is now being extended to other cars built by the General Motors Corporation. The application of chromium to gages and burnishing-tools by the Buick Motor Co. to prolong their life has been very successful. In one instance about 1,000,000 small spindles were chromium-plated instead of being carburized or otherwise hardened and were found to resist wear better. These spindles carry a very low load per square inch but are subject to extreme conditions of wear. Piston-pins plated with chromium are now in production and the Corporation expects that this use of chromium will be extended considerably.

The method followed to produce a permanent decorative effect on exposed parts is first to produce as smooth a surface as possible by plating with copper and nickel and buffing to a high finish, after which a light coating of chromium is applied. The cost is comparatively low considering the protection afforded. A steel base plated with 0.001 in. of nickel and then chromium plated will withstand from 80 to 100 hr. of salt-spray test, compared with 15 hr. when the same thickness of nickel-plating is not protected by chromium. The surface does not tarnish under exposure to the humid salt air in Florida and southern Texas.

Chromium trioxide, which contains about 50 per cent of chromium metal, is the chief material used in chromium-plating, which is not a very difficult process. The trioxide costs about 35 cents per lb. at present, but the price probably will decline as its use increases. High-current densities, with very short immersions in the baths, are used for plating radiator shells and bumper-bars. Hardness of the deposit can be controlled, but it is believed that the highest luster can be obtained by depositing the chromium in its bright modification.

Plug, thread and other gages protected by one plating last from 2 to 25 times as long as the best steel-gages. They are ground about 0.005 in. undersize and then brought up to size by plating. When finally worn, they can be deplated and a new coating applied. Burnishing-tools coated with chromium have been very successful because of the low coefficient of friction between this metal and others. Files for cutting soft metals can be plated with great advantage, as the soft metals do not clog the files. The plating of edged tools for cutting hard materials is not recommended, however, as the chromium has a tendency to fracture and roughen the work.

No instrument for measuring the hardness of chromium has been developed, but some of the soft modifications of chromium-plate have been measured by studies of the microstructure.

The discussion is comprised largely of an unusually large number of questions on all phases of the subject as submitted on question cards, and answers thereto by the author amplifying the information given in his paper. In addition, one written discussion on the cost of the process was presented for the purpose of eliciting further discussion of this phase of the subject. The discussion reveals a keen general interest in the possibilities of the practical application of chromium-plating for decorative effect, protection against rust and corrosion, and to give longer life to gages, bearing-surfaces and cutting-tools.

AUTHOR'S SUPPLEMENTARY REMARKS

W. N. PHILLIPS:—I have here two Oldsmobile radiator-shells. One was nickel-plated only and the other received the same thickness of nickel but was given a very light coating of chromium. Both were exposed for just about 1 month on the roof and when we brought them in we found a large number of rust spots on the one that had the usual nickel-plating.

The shells are first cleaned in the cleaning-bath and then go through the copper-tank and next through the nickel-tank. After they have been nickel-plated, they pass to the chromium-tank. The method of collecting the fumes is very important in chromium-plating. A straight hood such as is used commonly is not very successful, due to the fact that the fumes, so-called, are heavier than air. They really are a mixture of hydrogen and chromic acid. The acid is irritating and dangerous. The method used by the General Motors Corporation for collecting the fumes draws them off from the top. It does not lift them far and, with light suction, all of the fumes are withdrawn and the air is left free of them.

Bumper-bars go through essentially the same plating procedure on conveyor racks, with the tanks arranged longitudinally in succession.

[1] Factory production engineering section, General Motors Corporation, Detroit.

The installation put in primarily for the plating of gages and tools has two chromium-plating tanks, one fairly large and the other small. Occasionally a piece requires special attention and is put in the small tank, while the general lot is placed in the larger tank.

The Buick Motor Co., which I should say is the pioneer in the chromium-plating of gages, has plated a large number of these. The racking of the work is similar to that done in any kind of plating. Chromium on a burnishing-tool seems to wear for a long time and gives good results.

A new installation has just been made in the Oakland Motor Car Co. plant. It has a piece of overhead equipment that looks like a cream-separator. It is used for keeping the nickel bath clean and is very successful.

The photomicrographs tend to show the very fine crystalline structure that is obtained with chromium-plating and which is essential to produce the luster.

When plating a gage at the Buick plant a little more chromium is put on than is needed and then the excess is lapped off. The material laps down very nicely.

THE DISCUSSION

QUESTION:—Is it practical to plate cast iron to resist wear?

MR. PHILLIPS:—In the few applications we have made it seems to be very successful.

QUESTION:—Does the chromium tend to penetrate into cast iron?

MR. PHILLIPS:—No.

QUESTION:—Does it ever show this tendency on nickel-steel?

MR. PHILLIPS:—I never have seen it do so.

QUESTION:—Does chromium plate well on rustless steel?

MR. PHILLIPS:—We never have tried it, to my knowledge.

QUESTION:—Is chromium when deposited directly on steel rustproof?

MR. PHILLIPS:—It is to the same extent that nickel is by itself. A rather thick deposit of chromium is required to make an article entirely rustproof.

QUESTION:—Is it advisable to plate directly on steel or on brass?

MR. PHILLIPS:—That depends upon the use to which the article is to be put. If the use is to be mechanical I should say plate directly on steel, but if decorative effect is desired I should say do not. The treatment of brass depends upon the particular process that is used. Some find it advantageous to plate directly on the brass while others give the brass a coat of nickel first.

QUESTION:—Which is cheaper?

MR. PHILLIPS:—We prefer to put the nickel on first and think it is cheaper to do so.

QUESTION:—In plating gages is the chromium applied directly to the steel?

MR. PHILLIPS:—Yes, to steel that is cleaned perhaps better than for any other kind of plating.

QUESTION:—Is steel of any specific analysis especially suited for chromium-plating?

MR. PHILLIPS:—We have been able to plate everything from malleable iron up through the range and have not found any one analysis to be especially suited to the purpose.

PLATING ON ZINC AND ALUMINUM

QUESTION:—Can chromium be plated on zinc successfully and will it increase the resistance of the zinc to wear?

MR. PHILLIPS:—We have used a considerable number of zinc-base die-castings that were first given a plating of nickel and then chromium-plated and these pieces were used in connection with body hardware. One of the cars in which they were used has been out for more than a year and the material is standing up well. We have not tried plating chromium directly on zinc; I think it would be rather difficult to do.

QUESTION:—Has chromium-plating been tried on aluminum pistons, and with what result?

MR. PHILLIPS:—I have no direct data on that but talked with a man some days ago who said that it has been done successfully.

QUESTION:—Is it possible or practical to deposit a chromium coat on an aluminum spray-coated surface such as a wood propeller?

MR. PHILLIPS:—To me it seems rather difficult to electroplate any kind of metal on aluminum and have it stay on. However, within the last week samples have been brought to us from outside that look as if this problem is being solved. I have some samples in my office of aluminum sheets some of which have been nickel-plated and others copper-plated, and we are able to solder two pieces of the copper-plated aluminum together without stripping the copper from its base. I do not know how the plating is done. Chromium would be as difficult to plate on aluminum as nickel or copper, or more difficult.

QUESTION:—Would it be practical to plate small die-cast gears to reduce wear?

MR. PHILLIPS:—I do not know; it would depend partly upon the load the gears would have to carry and also partly upon how successfully the form of tooth could be plated. A number of things would enter into the problem and a trial would be the only way to find out.

SOME SUCCESSFUL APPLICATIONS OF CHROMIUM

QUESTION:—Has chromium been used on cutting tools?

MR. PHILLIPS:—It has been used and the edges are successful so long as no attempt is made to cut very hard material or to cut with too much impact. It is not successful in such cases, as the chromium breaks off, because it is brittle as well as hard.

QUESTION:—Has chromium-plating been used on jig bushings or jig wearing-parts?

MR. PHILLIPS:—Yes, and with some success.

QUESTION:—Can chromium-plating be applied over a soldered joint?

MR. PHILLIPS:—Yes.

QUESTION:—What has been done in plating crankshafts and brake-drums?

MR. PHILLIPS:—Nothing in a production way, so far as I know.

QUESTION:—What has been the experience with chromium-plating on piston-pins?

MR. PHILLIPS:—It seems to be very good practice.

QUESTION:—Has chromium-plating been applied successfully to valve-stems?

MR. PHILLIPS:—Yes, but it is questionable if that application is needed when the chromium-steels are so suitable.

QUESTION:—Will chromium-plating on hardened-steel mushroom tappets prevent scuffing?

MR. PHILLIPS:—I shall have to defer the answer to this question to some future time.

HOW OBJECTS ARE PLATED INTERNALLY

QUESTION:—Can cylindrical objects be plated internally without unusual procedure?

MR. PHILLIPS:—Yes, the only procedure is to use an

anode inside. A much more difficult piece of work is the plating of oil-cracking tubes that come in standard lengths. These are being plated every day both inside and outside by the simple expedient of putting an anode inside of each tube.

QUESTION:—Are you familiar with the resistance to wear and corrosion of plated water-pump shafts, particularly against wear of the packing-ring?

MR. PHILLIPS:—Considerable work has been done on this problem by one division of our company. Resistance can be obtained in two ways; one is to omit carburizing and depend entirely on the chromium. This did not work well in a certain car, as the packing was very hard and when it was squeezed the packing cut through the chromium. Very good results were secured, however, with some other shafts that were previously carburized.

QUESTION:—Would a chromium-plated shaft resist salt-water action as well as stainless steel?

MR. PHILLIPS:—We have made no tests on that. I believe, however, that if enough chromium were deposited on the shaft it might resist equally well. One salt-spray test on a chromium-plated piece has run 36 days continuously without any sign of the plating breaking-down.

FRED NEALE:—How thick was the plating?

MR. PHILLIPS:—About 0.05 gram on about 23 sq. in. of surface.

QUESTION:—Is the process suitable for protecting tools that work under high temperatures, such as intermittent contact with molten glass?

MR. PHILLIPS:—The Pittsburgh Plate Glass Co. is using chromium-plated rolls for rolling glass and claims some startling results. It reports that it has adopted cheaper materials for the rolls and these rolls have much longer life than any ever used before.

PLATE THICKNESS AND ITS CONTROL

QUESTION:—What maximum thickness of chromium has been evenly deposited commercially?

MR. PHILLIPS:—In my experience 0.015 in. That was deposited on a ring gage and was deposited very evenly.

QUESTION:—What is the thickness of the plating on plug gages?

MR. PHILLIPS:—We are using about 0.0005 in.; that is, when the gage is finally lapped it has that thickness of chromium on it.

QUESTION:—How is the thickness of chromium controlled?

MR. PHILLIPS:—By the time in the bath and the amount of amperes used during that time.

QUESTION:—Is any difficulty experienced in maintaining uniformity of thickness of the plate?

MR. PHILLIPS:—If the article has a variety of contours it is difficult to plate chromium or any other metal on it uniformly. Heavy deposits are likely to occur on parts nearest the anode and lighter deposits on the parts farthest away. The difficulty may be overcome in two ways; one is to move the piece of work a long distance from the anode, which reduces the ratio of difference in distance, or a special anode that conforms approximately to the shape of the article can be used. On articles such as plug gages it is not especially difficult to obtain an even, firm deposit. One division of the Corporation is omitting the lapping altogether. It has arranged a bath in which anodes are so placed that it is not necessary to lap the plating. It is working to a thickness of 0.0001 in., and 80 per cent of the pieces do not have to be lapped, while the other 20 per cent have to be lapped only a short time.

QUESTION:—How thick is the chromium-plating on the wristpins?

MR. PHILLIPS:—I do not know exactly. We plate them in about 10 min. The coating of chromium is very light but it seems to be sufficient. If we were to put on a heavy deposit perhaps we should have to resort to lapping them or something of that kind.

SOME PLATED GAGES NEED NO LAPPING

QUESTION:—Can the deposit on gages be so accurately controlled as to assure sufficiently true gages without lapping?

MR. PHILLIPS:—It can on the cylindrical type of gage but not entirely on the thread-gage. It is necessary to polish the edges of the thread-gage.

QUESTION:—How can a thread-gage be plated true to size diameter, pitch diameter and other features?

MR. PHILLIPS:—These gages are plated by placing the anodes far from the cathode and then the edges are merely polished with a piece of wood and a little abrasive. We find that the gages are entirely satisfactory.

QUESTION:—In gage work is the surface smooth enough without refinishing?

MR. PHILLIPS:—It can be made so. We plate on the gage and use it as it comes from the bath in some instances.

QUESTION:—Is it possible to plate inside a ring gage 5/8-in. inside diameter and obtain uniform thickness?

MR. PHILLIPS:—I think the gage should be plated first and then lapped out. The thickness would not be uniform after plating but would be when the lapping was finished.

QUESTION:—Will an unlapped gage wear as well as a lapped gage?

MR. PHILLIPS:—The smoother the surface on the chromium, hardness being equal, the better it wears. We can deposit the chromium just as smoothly as we can lap it, if not a little smoother.

QUESTION:—How are plug gages serviced?

MR. PHILLIPS:—After the plating has worn down we deplate the gage and then replate it. We never have to throw away a plug gage.

JOHN YOUNGER:—Can you use cheaper materials in jig bushings and jig parts and then chromium-plate them to get the same results?

MR. PHILLIPS:—We have not experimented with the cheaper materials but I think they should be tried.

QUESTION:—Would such parts be serviced as the gages are and the material thereby conserved?

MR. PHILLIPS:—I think that could be done.

QUESTION:—Would chromium-plating battery terminals prevent them from sulphating? And is chromium as good a conductor of electricity as lead is?

MR. PHILLIPS:—All I can say regarding sulphating is that chromium resists cold sulphuric acid satisfactorily, therefore plating the terminals might be good practice. I do not know the relative conductivity of chromium and lead.

QUESTION:—Would you expect that the corrosion would eat under the plate and peel it loose?

MR. PHILLIPS:—It might; I am not sure.

QUESTION:—Is it practicable to plate in holes 18 in. deep?

MR. PHILLIPS:—Yes, if there are enough of them to plate to compensate for the cost of equipping for them.

HOW HARDNESS OF PLATE IS CONTROLLED

QUESTION:—Can hardness of the plate be controlled by temperature of the plating-baths?

MR. PHILLIPS:—Partially; the hardness can be controlled by temperature and current-density.

QUESTION:—What abrasives are used for lapping chromium-plated gages?

MR. PHILLIPS:—Jewelers' rouge works fairly well, although it is slow. It gives a good lustrous finish.

QUESTION:—What is the cost of plating per square inch or per piece of say 5 sq. in., as for instance a spring-pin?

MR. PHILLIPS:—I assume the thickness would be about 0.0005 in. and I should say the cost would be about 1 cent per sq. in. for that kind of work. It is much less as the production becomes larger.

QUESTION:—Is there any place where one can have his products plated?

MR. PHILLIPS:—I should be glad to answer that question outside.

CHAIRMAN FRED A. CORNELL:—As a lapse from the tense eagerness of this technical discussion, we have a Scotch question reading: Would chromium-plating on a silver dollar make it last longer? It is asked by a professor of Ohio State University, John Younger.

MR. PHILLIPS:—I think every organization should have at least one Scotchman, and that one should be hired by the United States Government.

QUESTION:—Can small pieces be handled in the baths in a basket collectively or must they be connected individually?

MR. PHILLIPS:—They must be racked separately, so far as I know.

QUESTION:—Is it desirable to lap a piston-pin to secure a smooth surface before plating?

MR. PHILLIPS:—Absolutely; or centerless grinding may do fairly well.

EFFECT OF PLATING ON LUBRICATION

QUESTION:—Will chromium-plating interfere with the proper lubrication of a wristpin or any revolving part?

MR. PHILLIPS:—I do not know but I think it aids the lubrication.

A MEMBER:—I took part in a test on an automobile fan with a cast-iron bearing in which carburized shafting had been used previously. We experimented with chromium-plating and with no lubrication and the fan ran fairly successfully for 2 hr. with little or no scuffing, whereas a carburized shaft almost cut out the cast-iron bearing in less than 2 hr.

QUESTION:—Does the chromium seem to repel the lubricant in any way similar to its repelling action on water?

MR. PHILLIPS:—Oil seems to adhere to the surface of chromium in a satisfactory way.

QUESTION:—How does chromium affect friction between steel and another material, such as brake-lining?

MR. PHILLIPS:—The coefficient of friction between chromium and other materials usually is very low; they do not seem to hold onto chromium. I should think that with the proper thickness of plating and suitable backing a good effect would be obtained, with perhaps one reservation: the brakes might not hold so well, as the lining might tend to slide on the chromium.

QUESTION:—Does the chromium crack on a part that is subjected to shrinking or flexing?

MR. PHILLIPS:—I think it does if the shrinking or flexing is too great. A good example of this was some work that was done at our Hyatt division where an attempt was made to chromium-plate some drawing-dies that were used for making some deep cups of steel about 3/16 in. thick or more. The plug of these dies stood up splendidly but the rings failed, seemingly due to the slight stretching of the rings.

SECURING UNIFORM DEPOSIT ON IRREGULAR OBJECTS

QUESTION:—Is it not more difficult to chromium-plate irregular shapes than to nickel-plate them; that is, does it not require a more complicated set-up due to the difference in the throwing-power of the electrolyte?

MR. PHILLIPS:—More extensive equipment must be used but it need not be more complicated. If the electrode distances are ample the plating can be done successfully without any complicated set-up.

QUESTION:—Does not shading due to shape affect the deposit of chromium?

MR. PHILLIPS:—The deposit may be lighter in the depressions. However, we were able to plate a complicated radiator-cap satisfactorily from the decorative standpoint and get the plating down into all the peculiar shapes.

A MEMBER:—If the distance from the object to be plated and the electrode in the bath is very small, is the trioxide in the solution sufficient so that a good plate can be obtained without circulating the fluid between the two electrodes? I call them both electrodes in this instance. Assume that the distance is 1/8 in. and that one electrode is closer than the other, can a good plate be secured from the amount of solution between the two surfaces?

MR. PHILLIPS:—Yes, because the solution cannot be prevented from circulating. The instant the current starts flowing hydrogen is liberated and little bubbles form in the solution and keep working around through it all the time.

QUESTION:—Of what material must the anode be made?

MR. PHILLIPS:—Lead anodes are used in the Sargent bath and some of the producers of chromium-plate use lead while others use other materials.

QUESTION:—What is the covering-power of chromium trioxide in various thicknesses of plate?

MR. PHILLIPS:—Considerable mathematics will be needed to work that out. Chromium trioxide is about 50 per cent metal. The specific gravity of the chromium can be found in the engineers' handbook and the covering-power worked out from that. It is not very hard to do.

QUESTION:—What effects do alkali cleaning-solutions have on the finish?

MR. PHILLIPS:—That is an important point. In chromium-plating, if alkali is left on the work the finish, instead of being lustrous, will present an iridescent effect that may be pleasing but is not what is wanted.

COPPER PREFERRED FOR FIRST COAT

QUESTION:—Is there a preference between copper-plating and nickel-plating before applying chromium?

MR. PHILLIPS:—That phase of the process is the subject of a number of patents. I personally prefer nickeling over copper, for two reasons: first, because copper is red and if the chromium should be scratched the red would show through it, whereas nickel is relatively white; and, second, because the nickel is not attacked by the chromium bath, whereas the copper is. If a copper-plated object is suspended in a chromium bath to plate it and is left there awhile, the chromium bath will eat off all of the copper.

F. M. YOUNG:—Does not the copper adhere to the metal better than the nickel does?

MR. PHILLIPS:—Not at all. Electrical-goods manufacturers have omitted copper in nickel-plating for a number of years. They do not put any copper on irons or

electric toasters because, if they do, the nickel seems to tarnish more readily. These objects receive extra-severe treatment and the nickel adheres to them very well when applied directly on the iron or steel.

QUESTION:—Does the chromium tend to peel like nickel-plating?

MR. PHILLIPS:—The problem is exactly the same as with nickel. If the chromium is put on in the right way it does not peel.

One Plate-Buffing Operation Required

J. W. SAFFOLD:—Is it absolutely necessary to buff the nickel-plating before plating with chromium? The cost would be decreased materially if it were possible to omit this operation.

MR. PHILLIPS:—It is not necessary to buff the nickel but some surface must be buffed during the process if a smooth finish is required. It might be possible to buff the copper, apply the nickel in bright form, and plate the chromium on the nickel. One of the main requirements with steel is to make it smooth enough to put the preliminary coats on, and then one of these plates must be buffed to produce a smooth surface on which to deposit the chromium.

C. NEWMAN DAWE:—Are any buffing operations dispensed with, or are they performed the same as in the nickeling operation?

MR. PHILLIPS:—It is possible to omit the copper buffing which we previously thought was necessary, and its omission will pay for the chromium used. It has not been omitted in all cases. A number of manufacturers who have omitted the copper buffing, however, could not pay for the chromium in that way.

J. C. MILLER:—Would not a great deal more composition and buffing be required if buffing of the copper in the first place were eliminated?

MR. PHILLIPS:—No, the buffing of the nickel would require a little more time, and a little more composition would be used on that operation, but neither as much buffing nor as much composition would be needed as if both the copper and the nickel were buffed.

MR. MILLER:—Would not the copper have to be buffed so hard that considerable nickel would be removed in the operation?

MR. PHILLIPS:—It is very difficult to buff off much metal in these days. Long ago, when light deposits were put on, it was not unusual to buff through the nickel, but with the new practice of making heavy deposits, the amount buffed off is very small, as I have taken the trouble to ascertain by measurement.

QUESTION:—What happens to the plating if a radiator-shell is bent?

MR. PHILLIPS:—The plating will withstand considerable bending because it is so thin. It is like any other coating of hard material; for instance, baked enamel is hard but if it is not too thick the metal can be bent successfully without much fracturing of the enamel.

A MEMBER:—Do you know whether the reflecting power of chromium is great enough for the plating to be used in head-lamps?

MR. PHILLIPS:—The reflecting power of chromium, I understand, is rated about 60 compared with that of silver. On this basis it does not seem like a very promising material for the purpose, but I think if we measured the reflecting power of a silver-plated head-lamp that has been used a year we would find that a chromium-plated lamp would have a higher reflecting power than the silvered lamp at the end of the year. When new the silver-plated reflector has greater power than the chromium-plated reflector.

Cost of Chromium-Plating Analyzed

CHAIRMAN CORNELL:—Professor Baker, of the University of Michigan, has some written discussion on the cost of chromium-plating.

PROF. E. M. BAKER[2]:—I think I am correct in saying that, aside from the use of chromium-plated printing-plates, this interesting paper contains the first definite information on the utilization of chromium-plating to find its way into the literature.

A question I want to raise is one of cost, which the author has treated only briefly, and upon which an absolute dearth of information exists in literature. The expense of chromium-plating on plug-gages, tools and dies would seem to be fully justified, because the economies effected are greater than the cost of chromium-plating.

In the case of decorative plating, however, the use of the articles is not by the producer but by the consumer, and therefore the addition of chromium plate to another plate is more than likely to increase the cost. The benefits are considerable, as is shown by the difference in tarnish and scratch resistance between nickel and chromium-plated articles. I agree with Mr. Phillips's observation that a small quantity of chromium on a substantial base of nickel and copper gives a phenomenal increase in resistance to the action of the salt spray.

I have made a rough calculation of costs which I should like to submit for discussion and criticism: To plate 1 sq. ft. with 0.1 mil. (0.0001 in.) of chromium would require about 40 amp-hr., I believe, which might be applied by 10 volts and require, therefore, about 400 watt-hr. With plating current at 1.75 cents per kw-hr., that would amount to about 0.70 cent. For the blower I have taken a figure of about 20 per cent of the plating power. This estimate, which may be a little high, would make this power cost about 0.14 cent.

For this thickness of plate the cost of chromium metal, secured from chromium oxide, would be about 0.25 cent. There is also a cost for chromium solution carried out on the work when it is removed from the tank and rinsed. The solution so lost will figure up to about 0.60 cent.

The cost of labor will vary according to the kind of work that is done. If the objects are light, the cost will be less than on some heavier objects. A great deal depends on the size and shape of the articles. I have put the labor costs down as 1.50 cents.

Next is overhead, which includes rent; insurance; taxes; depreciation, which will be large because equipment of this kind must be written-off fairly promptly; inspection; supervision; license or development costs; and other elements of overhead. This would amount to 6.00 cents for the entire group. Together these items make a total of about 9.20 cents per sq. ft. for a plate about 0.1 mil. (0.0001 in.) thick.

Cost 1 Cent per Sq. Ft. Less Overhead

MR. PHILLIPS:—Professor Baker has assumed that we put on 0.0001 in. of chromium. This is more than most people use; in fact, our corporation is putting on only about one-half of that amount. The item of chromium does not make much difference, however, because he has allowed 0.14 cent for the blower operation, which would be correct if the fumes were exhausted in the usual way, that is, by drawing them up. Considerable power is re-

[2] Professor of chemical engineering, University of Michigan, Ann Arbor, Mich.

quired to raise these fumes but the method we use does not require so much.

I have not segregated figures on the chromium solution that is carried out with the work. I have figures on the total use of chromic acid. Labor cost, listed as 1.50 cents, is wholly suppositious, as Professor Baker said; I would let it stand as a general assumption. Overhead is one of the charges that people do not agree upon. I have, however, some costs that were obtained from a 6-months operation on an object which has about 5 sq. ft. of surface. The cost of the application, including everything except overhead, was about 1 cent per sq. ft. Roughly, the cost was 5 cents per object on the 6-months run.

The cost of chromium-plating is not a serious obstacle if one has use for a plate that has rust-resisting or corrosion-resisting properties. It will be cheaper, I believe, to use chromium than anything else to obtain these properties. Much more nickel would have to be put on to obtain the same result, and the unseen, uncalculated costs of the nickel are much greater than they are with chromium. Almost 100 per cent of good work can be secured with chromium, which never has been achieved with nickel.

PROFESSOR BAKER:—Is it your idea that as chromium-plating develops commercially for protection purposes, the present quality or degree of rust-resistance will be maintained with a minimum increase of present nickel-plating costs, or that improved quality will be obtained with a corresponding increase in costs?

MR. PHILLIPS:—That question would have to be determined as a matter of policy. The same quality could be supplied at perhaps the same cost or a better quality could be supplied at a slightly increased cost.

How Public Reacts to Appearance

MR. YOUNG:—What argument have you against the criticism that the chromium-plating is dull? Nickel-plating is in severe contrast with chromium-plating. It would seem that the dull glow is not wanted on some of the so-called high-class cars. Chromium-plating shines brightly but looks dull like lead instead of brilliant like nickel-plating.

MR. PHILLIPS:—We had exactly the same criticism when we put out a car finished with pyroxylin. Customers did not think it looked so attractive as when varnished. Even after the cars are polished they do not have the luster that varnish gives. We are so used to nickel-plating that some persons have a preference for it. To find how extensive that preference is, I went to 100 non-technical people with one piece of metal plated with chromium and another piece plated with nickel and asked them which they preferred. Eighty answered in favor of the chromium.

MR. SAFFOLD:—I believe that chromium gives the richer appearance. The tendency in the industry is toward richer-looking finishes and not toward shininess. Some of the larger agencies are finding it very difficult to sell nickel-plated radiator-shells because they are such a nuisance to keep polished. Many car-owners are saving the $15 extra cost of nickeled shells and having their cars come through with the radiator-shell enameled. Chromium-plating would obviate this and I think it would be well worthwhile.

MR. YOUNG:—I think the big production today is nickel-plated.

W. SMALLEY DANIELS[3]:—Our company tried to test public preference at one of the automobile shows by having part of our exhibit chromium-plated and part nickel-plated and saying nothing about it. No one seemed to notice the difference during the whole week. The two finishes looked about alike because they were buffed-up, but toward the end of the week it was noticeable that the nickel was tarnishing and the chromium was not.

THE ENGLISH LIGHT-CAR AND WHY

BY ALAN R. FENN[4]

ABSTRACT

ECONOMIC and other conditions that favored and practically forced the development of the light car in England, and the history of that development, are dealt with at length by the author. He recalls the light cars of the pioneer days of the automobile and then the putting on of weight about 1898 to increase reliability and riding comfort. He comments on the reaction that resulted in the advent of the cyclecar in 1911 and its quick demise because of its failure to perform satisfactorily. The keen interest of the public, however, indicated that a big business could be done in a light, efficient, cheap motor-car if it could be produced in a practical form. Genuinely light cars minus the crudities of the cyclecar then began making their appearance and quickly "caught on," due to the tax on gasoline, low selling prices, and automobile-club competitions that gave the public great confidence in these light vehicles.

Up to 1914 the light car, as distinguished from the cyclecar, was characterized by a two or four-cylinder engine of about 61-cu. in. capacity and was, as a rule, a two-passenger vehicle with not very generous equipment. It weighed about 1000 lb., had a speed of nearly 50 m.p.h. and consumed 1 gal. of gasoline to about 35 miles of normal touring-travel.

Following the World War, during which automobile production was almost entirely suspended, the tightness of money, a high automobile tax and the fact that the class of the public earning from $2,500 to $5,000 a year was hard hit, forced designers to exploit the small-capacity high-speed engine. Much had been learned about high-efficiency engines from aeronautic work during the World War, so in 1919 the light-weight low-horsepower general-utility family automobile made its appearance. It soon became a phaeton with a commodious body, and then an electric lighting and starting system, sliding front-seats, demountable wheels, and other equipment were added, which increased the weight. But the engine designer was able to keep pace with the demands on the powerplant without increasing the volumetric capacity much beyond 67.1 cu. in. and without sacrificing road performance. Compression-ratios were increased, crankshafts stiffened, and reciprocating parts lightened.

A certain clientele had become accustomed to large-car performance and luxury, however, and therefore, while in its earlier stages the light car became established purely on a price basis, the medium-price car and the higher-price specialized sports car appeared. The price range runs from $703.25 for the 7-hp. 91.5-cu. in. Austin to $5,000.00 for the complete four-passenger Martin phaeton. Three well-defined classes, as judged by engine dimensions, have engines of 91.5, 67.1 and 45.7-cu. in. piston displacement. Rated horsepower ranges from 7 up to from 12 to 24 and weights from 950 to 2240 lb. Maximum speed ranges from 48 to 67 m.p.h., and wheelbase from 105 to 108 in.

Specifications of the Morris-Cowley typical light-car

[3] A.S.A.E.—President, New Era Spring & Specialty Co., Grand Rapids, Mich.

[4] Sunbeam-Talbot-Darracq-Combine, London, England.

are given by the author, who presents a table of performance of 10 English and Continental light cars and also a table of running costs aggregating $750 a year, or an average of 7½ cents per mile as against 6 cents per mile for railroad fare.

Success of the light car as a commercial product is indicated by profits made by the Morris company, which made a net of more than $5,000,000 per year for 1923, 1924 and 1925. Upward of 60 different makes of light car are either being built in England or imported from the Continent, and nearly two-thirds of the present production of passenger-cars in England is of light-car type.

Closed bodies are beginning to predominate, and Morris and Citroen are making extensive plans to adopt all-steel bodies. Weymann flexible bodies are coming into demand more and more.

Two interesting new developments that may be significant are the Trojan general-utility car having a two-cylinder two-stroke 10-hp. engine of 90.7-cu. in. capacity and selling at $625, and the Constantinesco, which has an engine of similar type but of only 30.5-cu. in. capacity and the Constantinesco transmission that eliminates all change-speed gears and clutches. The latter car can average 28 m.p.h. over ordinary roads with two passengers.

Six-cylinder engine development is evident, and another year is likely to see a large number of semi-light six-cylinder cars of a distinctly luxurious type.

In the discussion the facts were brought out that the type of light car produced in England, and also on the Continent, was developed in its present size and design as a consequence of the heavy tax on motor-vehicles, which is based on engine bore. This tax is purely political and if it were removed the cars would become larger and the engines of greater horsepower.

Conditions in Europe and in the United States are very different and caution should be exercised in following English design. The standard 56½-in. tread in this Country must be continued because of the large mileage of unimproved highways rutted by horse-drawn vehicles that have this tread and also because the public expects all automobiles to carry three passengers on the rear seat. Wheelbase is fixed by the distance from pedals to front seat and the necessary clearance of the rear fender by the rear door. With tread and wheelbase fixed, weight cannot be greatly reduced if low-priced materials are used. Weight affects operating economy, but interest, depreciation and insurance are major items of cost, hence running economy will not be largely affected by slightly reduced fuel and tire consumption.

THE DISCUSSION

CHAIRMAN T. J. LITLE, JR.[5]:—We see clearly that the light car is by far the most important development of the year. Some of us have been studying this problem for a year at least, and some for 2 years, and think we see a great public demand for lighter vehicles in America. Circumstances are developing that seem to demand different types of car from those we have been using in the last 6 or 7 years. The streets of all of our principal cities are becoming greatly congested. The driving public is demanding cars that will have a better performance in city traffic and that are smaller and more easily parked. Americans have been working along this line recently, but in Europe the engineers have been developing wonderful little and medium-size cars for several years. We have men in this Country who are well qualified to speak on this subject but the Council of the Society thought it proper to induce the most expert man in this line abroad to address this meeting. Some will take issue with some of the statements in his paper. I think this is the beginning of a great national discussion in automotive circles on the light car.

Mr. Fenn said that the sale of light American cars that have been introduced into England is declining. That is as it should be, because they are not meeting the English conditions. We shall find in this Country that as the public demand changes the builder will change his design and ideas of construction. I predict that most American companies will have a decided change of heart in the next year or two as to the making of light cars. I also predict that the English and American light-cars will be essentially alike about a year from now, because, as Mr. Fenn said, the English are going to a slightly heavier car, with slightly more power and a six-cylinder instead of four-cylinder engine, and we are doing the same thing here.

FACTORS THAT FIX DIMENSIONS AND WEIGHT

H. M. CRANE[6]:—Practically all of the conflict of opinion surrounding the light car is based on the fact that when two men get together and discuss it they are not talking about the same thing. Mr. Fenn has told clearly why the English light-car is what it is today. He admits that rating the lightness of a car by the size of the engine is not a strictly accurate method. It is a natural way on the other side; it would not be natural here, for very definite reasons which center largely in the advertising departments.

I think Mr. Fenn would agree that the operating cost of a car depends primarily on the weight. Engineering compromise enters into the question whether a car can be made light in one way better than another way. The preponderating influence in the weight of a car is its linear dimensions, and that is a matter on which we have to reach some agreement on what we are talking about. Linear dimensions are set by certain local conditions. The two linear dimensions that are of predominating importance are the tread and the wheelbase.

The tread in this Country became standardized at approximately 56 in., although a number of companies shipped 60-in.-tread cars to the South due to the use of wagons in that part of the Country which produced road ruts 60 in. apart. The standard tread today is still 56 in. largely because, while we have many thousands of miles of road on which the tread does not make any difference, enough rough rutted highways still exist to have a serious bearing on the quantity-production car. It probably would be much easier to sell a $7,000 car with a narrow tread in this Country than to meet the requirements of the public with a car that has such a tread to sell at $500. However, the tread is not only regulated by ruts in the road; it is related to the public demand for a lower appearance and also to the seating capacity.

The demand for lower cars has brought the rear-seat cushion down until it is between the wheels where the width of the cushion is fixed absolutely by the tread of the car and the tire diameter. In large cars with fairly large tires, it is not possible to place a cushion more than 44 in. wide at that point, although we still optimistically call it a three-passenger seat. On a smaller car, with smaller tires and especially when the car has less spring action, it is sometimes possible to utilize 45 or 46 in. at this point for the seat. If 8 in. is subtracted from that, as would be necessary with a 48-in. tread, which is a good tread in other respects for a short-wheel-

[5] M.S.A.E.—Chief engineer, Marmon Motor Car Co., Indianapolis.

[6] M.S.A.E.—Technical assistant to president, General Motors Corporation, New York City.

base car, it obviously will produce a 36-in. cushion, which is comfortable for two passengers and no more.

Two-Passenger Capacity Insufficient Here

E. S. Jordan said at the Annual Dinner in 1926 that a thorough examination of market conditions in this Country indicated that the most popular seven-passenger car in the United States was the Ford. That is no joke; the public has been educated to expect to get three people on the rear seat of any car, perhaps with a little pressure; not only that, they also put three on the front seat. I think an ordinance was passed in Detroit recently making it illegal to do so.

The wheelbase is tied-up equally with carrying capacity, especially when we are dealing in sedan or salon-type bodies that have four doors, because the controlling dimension on a car of that type is the longitudinal distance from the rear of the steering-wheel to the front of the rear road-wheel, if the steering-column is located in a comfortable relation to the pedals. The reason is plain. The steering-column position fixes the location of the back of the front seat, the rear of the front seat in normal body design fixes the front of the rear door, and the operating of a rear door that is wide enough to be used comfortably fixes the position of the rear wheel. The figures on that particular dimension of wheelbase indicate a very close relation between the English or Continental light-car and cars of the Ford and Chevrolet class. They usually run in the range of 100 to 105 or 106 in. No reason to expect variation in this exists. By sacrificing the ability to enter at the side of the car, it is possible, in very light cars like the Austin, to reduce the wheelbase considerably further and thereby make a big cut in the weight, which is very desirable, but we are still in doubt in this Country whether the demand is sufficient to justify the attempt to market a large production of two-passenger cars. The capacity would have to be limited to two passengers to bring the weight much under 2000 lb. with the low-priced materials that are used in large quantity-production.

Weight affects the economy on the road. Other factors also affect running cost. One could easily make a formula for the whole relation. Carbureter efficiency or gasoline efficiency is a matter of ton miles per gallon, with a factor that modifies this consumption in proportion to the acceleration speed of the car on high gear, or its ability to climb hills on high gear. A four-speed gearbox gives greatly improved gasoline economy by enabling the car to run on a higher gear with less hill-climbing ability than is afforded by a lower gear. For this reason a typical English light-car and a typical American light-car cannot be compared as to gasoline economy unless their acceleration ability is known definitely.

I am trying to state facts and to lay a groundwork on which comparisons can be made. I think if we do that we shall reach the conclusion that I personally have reached. Had I been an English engineer working under English conditions, undoubtedly I should have produced much the same type of car as has been produced on the other side. If Mr. Fenn had started over here and had come through the history of the motor-car as we have done, I think he would have produced cars very similar to those we have produced.

Bases on Which Efficiency Is Measured

Efficiency is a dangerous word to use loosely. I have always been irritated by hearing high-speed high-efficiency discussed by persons who think of the term as thermal efficiency. Efficiency can be defined as a result obtained in proportion to something used in producing the result. It can be the thermal efficiency reached in the burning of gasoline in an engine; that is, the amount of actual horsepower obtained in proportion to the horsepower available in the heat units in the fuel.

Efficiency also can be based on other things; thus, the efficiency of an engine design may be represented by the horsepower obtained per dollar of cost, which is an important consideration in designing light cars in this Country, where the light car must be a low-priced car. Efficiency can also be based on the maximum mean effective pressure obtained, which is likely to be a good measure of aviation-engine practice, in which the engine usually is run at maximum mean effective pressure at full load. Efficiency can be measured on gas consumption at full load or part load, the latter being, as a rule, more important in this Country as a measure of cross-country gasoline economy.

Again, and as a rule this has been done so far in discussing the high-speed engine, we can discuss efficiency in terms of output per cubic inch of piston displacement. I submit that, unless piston displacement is an object of taxation or is limited by racing rules, this last use of the term efficiency is least important of all; in fact, it is dangerous to allow ourselves to be hampered by that point of view.

If we think of the English tax of $110 yearly in terms of the Ford or Chevrolet, and realize that thousands of these cars change hands every year at from $50 to $80 or $90 apiece, we can understand why such cars are handicapped in selling over there. The situation has no engineering bearing. A man can buy a fine automobile here for a first payment that is no more than the English tax on our lowest-priced car.

CHAIRMAN LITLE:—I think the body engineer sometimes has something to do with this problem. One of the things that worry the body designer is to make the passengers comfortable by providing ample leg room. Then, too, the top should be high enough not to interfere with top hats. It is a great problem to make occupants comfortable when seated in small cars, but until designers do so, small cars will not be successful in this Country.

English Design Forced by Political Tax

A. P. BRUSH[7]:—I understand that the English tax is political rather than based on engineering practice. If an engineer should plan a tax rather than a car only, I expect he would base the tax on the social burden of the car; that is, weight as related to road wear, or cost and maintenance in relation to the investment and operation costs. Does Mr. Fenn, as a designer, believe the design of the English light-car would be different if the tax were so based instead of being based on cylinder bore? Is the development of the small-bore high-speed engine, low-gear-ratio cars the result of actual engineering advantage to the user or is it more in obedience to the arbitrary tax imposed?

ALAN R. FENN:—The tax is purely a political measure. The engineering phase was not consulted and if this tax is removed, a marked change in the whole atmosphere of design will be seen.

MR. BRUSH:—That points to an assumption with which I cannot wholly agree, that if we be patient for a year or so, we shall find that the English and American light-cars will be identical. I think I am right in saying that the general policy of motor-vehicle taxation in the United States is to base it on cost and weight rather than on bore. For that reason we have a freer hand to

[7] M.S.A.E.—President, Brush Engineering Association, Detroit.

do our engineering more in the interest of the customer, to meet his desires and needs than to meet a politically imposed arbitrary tax.

MR. FENN:—To prevent any misapprehension may I say that it will be a long time before the pound-per-horsepower tax is removed, for this reason: At the present time England is short on the budget, and will be for some time in the future. About £20,000,000, or $100,000,000, will be collected this year through the motor-car tax. When the tax was imposed it was declared definitely by the politicians that this fund should be applied to road improvement, but they found the sum was so interesting that they cut down the amount of money that was to be devoted to roads to about £14,000,000, or $70,000,000, I think. The balance is taken by the Treasury. From the budget point of view I believe the chancellor will think twice before he will part with a certain £6,000,000 ($30,000,000) and probably more. At a time like this he would rather retain a sure thing than take a substitute measure he knows nothing about.

MR. BRUSH:—Since we are all politicians in America, I suggest that we should prevent the English policy from being put into effect here. The same revenue might be realized and still leave the engineer a free hand if a tax were based on cost, weight and fuel consumption instead of on the bore of the engine.

CAUTIONS AGAINST ADOPTING ENGLISH DESIGN

B. B. BACHMAN[8]:—The particular impression I have gained from Mr. Fenn's paper, plus such personal observation as I have been privileged to make in England, is confirmatory of Mr. Crane's closing remarks. I feel that we should be totally unjustified in transposing to this Country without much thorough and careful consideration, the logical engineering development in England that is based on this arbitrarily and politically developed taxation scheme and the topography of the country, the character of the roads and the construction of the towns. I have been impressed by the apparent readiness with which some American engineers accept development abroad as a model to follow. There is some justification for this.

Mr. Fenn did not discuss the problem of parking. Those who see the difficulties that are being encountered and the restrictions that are being placed upon the operation of the motor-vehicle as the American wants to use it by the increasing congestion in our large centers must feel that a revision of design which will restrict the dimensions and enhance the ability to maneuver will further increase the usefulness and adaptability of the automobile to the purposes of personal transportation. A grave question arises in my mind whether this is the only possible solution. It seems to me that we must have a broader outlook and consider what can or should be done, or what probably will be done, as a matter of evolution. As I see it, one development that will come out of this condition of congestion is not merely a compacting of the automobile but a dispersion of industrial and sales activities, particularly as regards retail sales.

OPERATING COST NOT A MAJOR FACTOR

J. H. HUNT[9]:—I have made an estimate of the cost of using a light car, by which I mean a car that is lighter than the lightest cars we can buy today in America. Interest and depreciation will decrease with the reduction in the weight of the car, assuming that the cost per pound is somewhere near what it is in other types of vehicle, although it looks as though we could not reduce the cost per pound proportionately because the number of operations cannot be reduced. Taxes will be reduced as size is decreased, regardless of the basis on which they are imposed. Insurance will not change much, since liability insurance is the most expensive item. Garage and parking charges are not yet reduced for small cars. If we had a very small car we could not secure any lower rates for this part of the cost of operation. Tires, gasoline, oil, and other running costs will be reduced but the figures for these are considerably smaller than the other charges that have been mentioned.

Therefore it seems to me that the question of the use of the light car in America comes down to a matter of convenience rather than cost. At the Annual Dinner in New York City, R. H. Grant said that the prospect for the future is the sale of additional cars to take care of the family's transportation needs because the man of the house uses the automobile to go to his business and leaves the family without transportation. I think, however, there is a pronounced tendency for the head of the family to leave the transportation at home. This does open a field for a considerably lighter car than has so far been used, for convenient operation in traffic and for business use.

Whether a company will be willing to take the risk of going into this field, knowing that the use of such a car will be greatly restricted as compared with the use of the light cars already available, is a question. I personally should hesitate to take the responsibility of recommending the necessary expenditure, but there is a possibility for some company to enter this field. A company that can meet this demand which I think I see and surmount the difficulties created by the low price at which cars of greater capability are now supplied has a certain opportunity.

I should like to ask Mr. Fenn what are the weights of the engines in the cars he discussed and to have him tell what advantages he feels the small-displacement high-speed engine possesses as compared with an engine of equal power but greater displacement and slower speed from the standpoint of over-all cost. I have noticed that some of these engines of high efficiency, to use the term as defined last by Mr. Crane, seem to weigh as much per horsepower as some of the other engines in use in large cars.

MR. FENN:—I cannot give the weight of the engine by itself as practically all of these little cars are built with the transmission attached to the engine. The weights range from about 296 to 350 lb.

As regards the advantage of the so-called high-speed high-efficiency engine as compared with the low-speed engine, are we not concerned with the question of high torque at high speed and at low speed? In preparing my paper I came to the conclusion that it was better to deal with the small-car question as I have done rather than from the engineering angle. Questions on the purely technical side would better be answered by correspondence.

WITHOUT TAX CARS WOULD BE LARGER

CHAIRMAN LITLE:—Will you elaborate on your answer to Mr. Brush regarding the effect it would have on the engineering of these small cars in England if you were not hampered by the restriction of a political tax?

MR. FENN:—No doubt the tendency would be to increase the number of passengers all around. Even under present conditions a survey of the designs at the London

[8] M.S.A.E.—Engineer, Autocar Co., Ardmore, Pa.

[9] M.S.A.E.—Engineering department, Chevrolet Motor Co., Detroit.

Automobile Show last October revealed a tendency to increase the seating capacities a little, if for no other reason than this: In our industry we will have to think of the export market. We must bring up the cars to conform to local conditions in the younger countries, therefore weights will increase and we must find some way of increasing the power.

MR. BRUSH:—I had more in mind the engineering characteristics. Will the small bore, long stroke and the high speed be continued or be modified? Will the engineering characteristics or engine design and the gear-ratio of the car change, or will they follow the same line?

MR. FENN:—This is a subject of much controversy. One school advocates the low-duty engine and another school the high-duty engine. The best example of what we call the low-duty type is the 12-hp. Austin, which would be regarded as rather flabby and uninteresting to drive, but it goes on running indefinitely as opposed to the snappy type that requires more attention. I think probably the bore-stroke ratio will stop where it is, but that is only my guess.

MR. BRUSH:—Then that controversy is not having a chance to work itself out on a purely engineering basis because of the tax imposed?

MR. FENN:—We cannot move much at present.

MR. BRUSH:—That was the point I wanted to emphasize; the tax situation did not give you the engineering scope we have here in America.

G. L. HOLZAPFEL[10]:—Europe and America are continually teaching each other, and it is the ability to put aside prejudice and adopt new ideas, even if they come from the other side, that puts vitality into a company. In every country automobile design seems to settle into a rut. I do not think the characteristic design of cars in any country can be said to be the most desirable for that country. For illustration, in most European countries designers are likely to sacrifice convenience and comfort for economy, while in America they put too much weight and power into a car without, in my opinion, attaining any comfort or convenience that could not be attained with a lighter car. The man who buys an expensive car usually does so because he does not like to be seen in a cheaper one and buys a heavy car because he has the mistaken idea that only heavy cars can be comfortable.

It is interesting to study what one might call the I-B, or iron-bone, factor of a car. Thus, a Ford weighs 1660 lb., and for one passenger who weighs 100 lb. the I-B factor is 16.6. With five heavy individuals whose weight aggregates say 1000 lb., the car would be loaded to capacity and the I-B ratio would be 1.66. A Locomobile that weighs 5000 lb. would have I-B factors of 50 and 5, respectively. A comparison of such figures shows the great variation in the weight of metal carried per pound of passenger. Even when lightly loaded the Ford carries three times as much metal per pound as the Locomobile when heavily loaded. Obviously the answer to this is to make light cars for two passengers, for the time seems to be coming when the average family will not be content with one car but will need two or more and will then select the one best suited to the load to be carried.

Light cars must not, however, be reduced in length, except the two-seaters. To design an automobile, one should first arrange a dummy body to accommodate the required number of passengers in comfort, then build a chassis to suit it. Judging by the restricted space for the driver in many American cars, this practice is not followed, and in only a few cars is the driver's seat adjustable. No one would have dreamed of buying a bicycle that was not adjustable, but today the public buys expensive cars, the seats of which offer no adjustment. Let us have adjustable seats at any cost.

No small car can be made to look well unless the overall height is low. This means lower seats, a few inches farther from the pedals, but we must have that extra room, even if it means lengthening the chassis.

It is worthy of note that one English builder is already on the market with a front-wheel-driven car. The possibilities of this type of drive in the construction of light well-sprung vehicles are so great that it must eventually supplant the somewhat unmechanical method of pushing the car along by the rear wheels.

[10] M.S.A.E.—Research engineer, Standard Oil Co. of New Jersey, Elizabeth, N. J.

QUESTION:—The mortality of very small cars is high when they are parked with large cars at the curb. Does this condition obtain in England?

MR. FENN:—I do not think so. Our mortality of fenders, and I understand now why you call them fenders, is rather high and we are gradually adopting bumpers, which will be standard equipment soon. But I do not think the little cars are imposed upon by the big ones.

QUESTION:—Is an indirect gear commonly used in fourth-speed transmission?

MR. FENN:—Never. The only firm that made a real attempt at it was Rolls-Royce with an indirect fourth speed in 1912.

QUESTION:—What would the English tax be for an 8.6-hp. car?

MR. FENN:—Any fraction over 0.1 hp. is assumed to be 1.0 hp. For an engine of 10.2 hp. the tax is £11, or about $55.

CONVENTIONAL FOUR-CYLINDER ENGINE POPULAR

QUESTION:—Has any light car using an engine differing from the standard straight-line construction achieved popularity? At what engine-speed does an average light-car peak?

MR. FENN:—The peak is at about 3000 r.p.m. No car that does not have a conventional straight four-cylinder engine has attained to any real popularity.

QUESTION:—Please explain your statement regarding uncertainty of the future of the steel body. This is a vital subject, as very light bodies may revolutionize car design.

MR. FENN:—I think the main reason for uncertainty is that we do not know anything about steel bodies yet. A large number of persons in the industry think that the public will not take the steel body seriously because of the objection to the metallic effect of such a body. The public in England is very sensitive when buying cars in regard to the shutting of a door. One of the first things they do when inspecting a car is to open the door, and if it closes softly they think the body is good but if it has a tinny sound they think it is not so good.

SEDAN BODIES AND PNEUMATIC UPHOLSTERY COMMON

To secure enough body space we have had to give considerable overhang to the outer part of the car. It is surprising how comfortable some of the bodies are, but I imagine no American would get into some because he is afraid of bumping his head. I should like to emphasize the open phaeton although the sedan is rapidly gaining in popularity. The all-weather equipment, such as side screens and so on, has been studied carefully and good jobs are made. Pneumatic upholstery is becoming very popular and makes a simple job. One of our great

troubles is with the upholstery-workers' union. The upholsterers and the tin-workers are two elements we do not want to deal with, and every one tries to think of ways to avoid these trades. We use detachable steel wheels always. The biggest output of small cars in England is about 2300 a week.

QUESTION:—What is your opinion of the application of the supercharger to the high-grade light-car?

MR. FENN:—None whatever.

QUESTION:—Why does the American car cost 100 per cent more in England than it costs the purchaser in America?

MR. FENN:—That is a question of economics. I should be pleased to give a dissertation on it but it would take a long time.

QUESTION:—Why are the headlights carried on the fenders?

MR. FENN:—Mainly because of the cheapness; it saves using lamp-brackets. Moreover, the law specifies that the lights be spaced apart the full width of the car but is not enforced rigidly, as we could not possibly light the maximum width.

QUESTION:—Is the valve arrangement showing a tendency toward valve-in-head design or the usual L-head type that is common in England?

MR. FENN:—It is toward valve-in-the-head design.

QUESTION:—Will the English light-car owner pay a premium for a fuel that prevents detonation?

MR. FENN:—The question hardly arises in England. Our gasolines are of much better quality apparently than here and most of the engines are overhead-valve engines. Detonation does occur in certain types of engine. In that case about a 50-50 gasoline and benzol mixture is used. Benzol is well distributed throughout the country. In most places one will find tanks with this mixture if he wants it.

INTERNATIONAL TRADE

IN 1926, exports valued at $2,310,000,000 or 48 per cent of our total went across the North Atlantic, as compared with 12 per cent or $564,000,000 to Asia and 9 per cent or $443,000,000 to South America. This is truly an impressive preponderance and one by no means confined exclusively to raw materials, since Europe takes more than 28 per cent of our total exports of finished manufactures. The tremendous drain on Europe's resources during the war and her post-war period of retrenchment and readjustment have by no means caused that continent to be displaced from her position as our foremost oversea trade outlet.

In 1913 we took 5.6 per cent of the entire exports of the United Kingdom, whereas for 1926 our share, according to preliminary estimates, was 9.4 per cent. In 1913, Germany sent us about 7.0 per cent of her entire exports, and in 1926 our proportion was 7.8 per cent. In 1913, we received 6.1 per cent of the entire exports of France, while in 1926, November and December being estimated, she sent us 6.4 per cent. About 6.5 per cent of all Spain's exports came to this Country in 1913, whereas our share of her exports in 1925 was 10.1 per cent.

The recent acknowledgment of the existence of the British Commonwealth of Nations, replacing the British Empire, seemed to some casual observers to be but a political formality, perhaps a weakening of the influence and power of the mother country, but in reality it involves a consolidation and strengthening of Britain's world economic and commercial position. Internal differences have been ironed out, public acknowledgment has been made of a recognized fact, and before long, undoubtedly, a tightening of the economic bonds within the empire, which is bound to react upon international trade from many angles, will be made evident to the outside world. That on the whole the United States will benefit economically by the new arrangement seems probable, not only because of a regularization of tariff and other economic relations, but also through the strengthening of a group of major commercial areas, which account for nearly 44 per cent of our total exports and over 36 per cent of our imports. The establishment by various units of the Commonwealth of direct diplomatic representation with the United States should expedite any adjustments necessary to facilitate better commercial relations.

The stabilization of the Belgian franc and the effort now being made in the same direction in France, Poland, Italy, and elsewhere may temporarily make it more difficult for the people of these countries to export to foreign buyers taking advantage of exchange depreciation, but in the end their costs and credit facilities will be materially stabilized and their competitive powers thereby strengthened.

Some apprehension has developed in American export circles over the organization of a dozen or more international trusts or cartels in Europe, including such commodities as steel, wire, cement, zinc, laths, potash, and other chemicals. Obviously these enterprises would, if undertaken in the United States, be entirely illegal and contrary to long-established trade principles. The German government has announced that it favors the steel cartel, and the Franco-German potash agreement was negotiated under government auspices. Obviously their competitive possibilities should by no means be ignored even though the very large volume of output and domestic demand in this Country and the superiority of our production technique, waste elimination processes and standardization give the American industry formidable advantage in any such commercial conflict. It is yet too early to make any appraisal. The industrial countries of Europe will inevitably become more intensive competitors of ours in all parts of the world. However, since many of them need American raw materials, machinery, office equipment, and other wares of which they do not produce adequate types or quantities, we will benefit by the prosperity of their export trade, which in fact forms a far larger portion, from 50 to 85 per cent, of their total trade than is the case with us. Moreover, with their ever-increasing purchasing power at home and their cultivation of former markets and penetration of new ones, we will inevitably share in the general prosperity that their recovery is bound to stimulate in all parts of the world.

In iron and steel, the producing nations of Europe still lead us in most of the markets of the world, because of low production costs, although in a few of the different varieties we are able to hold our own. Great Britain's production costs are only a little less than ours. European governments are giving special aid to goods which are competitive with ours by subsidies, credit insurance and a closely linked politico-economic program in international relations which is sharply differentiated from the traditional and sound American policy of "keeping the government out of business." We are obviously faced with a new era of vigorous world trade rivalry.—From an address by Director Julius Klein, Bureau of Foreign and Domestic Commerce.

Fields for Motorcoach Operation

By R. N. Graham[1]

Metropolitan Section Paper *Illustrated with* Drawings and Photographs

ABSTRACT

DEFINITION of the fields for profitable operation of motorcoaches is undertaken by the author on the basis of personal experience in the concurrent operation of motorcoaches and street-railways during the last 5 years. The operations include city service in Youngstown, Ohio, and interurban service from Youngstown to Cleveland and Akron, Ohio, and to Meadville, Pa., distances of 50 to 70 miles. The city service in Youngstown is analyzed comparatively as to transportation provided, passengers carried, gross revenue earned and operating costs on virtually parallel street-car and motorcoach lines. One pair of routes is 2½ miles long and the other pair a little more than 1 mile longer. The analysis shows a somewhat greater earning capacity for the motorcoaches than for the street-cars on the shorter route but that the motorcoaches on the longer route are operated at an actual loss whereas the street-cars earn a profit.

These facts are held to prove that single-deck motorcoaches cannot be operated profitably in cities on routes much longer than 2½ miles and that it is convenience of service rather than a desire to ride on rubber-tired vehicles that determines the choice of the public as to the type of vehicle in which it will ride.

Factors that definitely limit the possibilities of profitable motorcoach-operation in cities are specified, based on general averages for the whole Country, such as fixed flat rate of fare, length of route, size of vehicle, load factor, and operating costs. On the basis of these factors it is asserted that the absolute limit of distance over which 25-passenger motorcoaches can be operated profitably in cities is 3 miles. Double-deck motorcoaches cannot be used profitably on longer routes at the standard rate of fare because they cannot be operated safely by one man.

Fields in which motorcoaches can be operated profitably are specified, and the author advocates a special supplemental service for which a relatively high rate of fare may be charged for a comfortable express ride from the suburbs into the heart of the city. The field of suburban and interurban service presents a great future for the motorcoach, he holds, and the interurban operations of his company in northern Ohio are described and shown to be more profitable than the city operation and also to produce a larger revenue per mile than the interurban electric-railway operations.

Itemized operating and maintenance costs on the Youngstown motorcoach-operations are given and show that the maintenance costs and total cost of service increase by successive years as the equipment becomes older.

A number of suggestions to motorcoach engineers and builders as to needed improvements are given as a result of the author's 5-years' operating experiences.

Extended discussion of the paper relates to motorcoach operations by the street-railway company in Baltimore and analyses of operating costs and revenues of individual routes, opportunities for motorcoach operation in other city-services than those specified by the author of the paper, the favorable effect on street-car earnings of the use of tracks laid at lower costs than would be involved if they were to be put down at present costs, the problem of special service at special rates of fare, improvements in power-operated brake-mechanism, and the unsuitability of fabric linings for power-brakes.

MOST of this paper will be devoted to indicating what I regard as the field for motorcoach operation in mass transportation in cities as a result of my personal experience. I do not presume to express an opinion on subjects with which I have had no experience.

The company with which I am connected has been operating motorcoaches about 5 years and has operated them a total of 13,609,365 miles. About one-half of this mileage has been in city operation and the rest in suburban and interurban operation. Most of the city motorcoach-operation is in Youngstown, Ohio, which probably has about 160,000 inhabitants. The rest is in New Castle and Sharon, Pa., and Warren, Ohio, whose populations range from 20,000 to 50,000. A number of our local suburban motorcoach-lines connect Youngstown with the surrounding communities, and three interurban lines connect Youngstown with Cleveland, a distance of about 70 miles; with Akron, about 50 miles; and with Meadville, Pa., about 70 miles. These lines are shown in Fig. 1.

The gross revenue from the entire motorcoach-operation for the year 1926 was $1,344,072.40. In the City of Youngstown, where we operated coaches 2,027,964 miles, the gross revenue from motorcoaches was $638,145.11. The gross revenue of both street-railway and motorcoach operations was $2,102,877.56. The number of passengers carried in Youngstown was 23,269,544 on street-cars and 10,380,431 on motorcoaches.

The first use of motorcoaches in urban transportation by the Youngstown Municipal Railway Co. was in September, 1922. The gross revenue, number of passengers carried, and the mileage operated in the City of Youngstown for that year and each succeeding year are given in Table 1. The company now operates 57 motorcoaches in the city and also operates about 80 street-cars in Youngstown, which is approximately the same number it operated in 1921.

TABLE 1—REVENUE, TRAFFIC AND MILEAGE OF CITY MOTORCOACH-OPERATION IN YOUNGSTOWN, OHIO

	Gross Revenue	Passengers Carried	Motorcoach Miles
1922	$28,453.56	510,929	112,901
1923	228,425.53	4,032,882	918,644
1924	444,700.25	7,387,091	1,511,091
1925	511,347.59	8,361,236	1,738,930
1926[a]	638,145.11	10,380,431	2,027,964

[a] Motorcoaches operated, 57; street-cars operated, 80.

Changes in Transportation Conditions Since 1910

In our conception of our obligation to furnish transportation to the communities served we differentiate in

[1] Manager of railways, Pennsylvania & Ohio Railways, Youngstown, Ohio.

no respect between a street-car and a motorcoach. Both are regarded as proved agencies of transportation and as the tools of our trade. It is not our intention to operate either where the other can give a more satisfactory service to the public and larger financial returns to the company.

A radical change in the conditions that have been peculiar to the industry of mass transportation in this Country began with the year 1916. Previously the electric-railway industry, together with steam shuttle-service, which comprised the only customary instruments of mass passenger-transportation, was, like every other great industry of this Country, extremely liberal in the use of man-power because wages were low. Subsequently the growing demand for man-power and the consequent increase of wages increased the expenses of this industry enormously. Relief from this situation, as with every other industry, was by an increase in the price of the product or service. Unlike other industries, however, the transportation industry could increase its prices only after a long legal and political endeavor. Ultimately, no doubt, an increased price for the service that was proportionate to the increase in expense would have been realized had not another contemporaneous development greatly affected mass transportation.

Many persons have a conviction that electric railways failed in some way to keep step with the progress of the world and feel that they are in difficulties because their activity is becoming obsolescent. This confusion of thought is increased by the fact that, in the decade when increasing operating-costs and increasing use of the private automobile embarrassed the street-railway companies, the motorcoach was in process of development. The tendency has been to reason that the difficulties of the railway companies are in some way a natural result of the development of a radically new type of transportation that they either would not or could not use and that is to succeed the electrically propelled rail-vehicle.

Vehicle Type Does Not Alter Problems

The problem of mass transportation, as distinguished from a service directed primarily to the comfort of the individual passenger, is to provide for the carriage of passengers in groups from point to point in an urban community. Therefore it is evident that the generic problems which such an industry faces are the same regardless of the type of vehicle used. The difference between transportation of a group with a motorcoach and transportation of the same group with a street-car is simple compared with the great problems in transportation with either type of vehicle that are presented by the constant increase in the use of the private automobile on the one hand, or, on the other hand, by the constant increase in operating costs.

When motorcoaches first began to be used in this Country rather persistent talk of the "rubber urge" was heard. The idea back of this was that the motorcoach was so much more attractive as a conveyance than the street-car that persons who had ceased to ride in street-cars would refrain from using their private automobiles and again avail themselves of public transportation if the companies used motorcoaches instead of street-cars.

It is impossible to define the field of the motorcoach in city transportation without considering most carefully whether this "rubber urge" exists. If an impelling motive exists in the minds of the public that will cause them to ride in motorcoaches in preference to using their private automobiles when they would not avail themselves of other forms of public city-transit, then the motorcoach will occupy an essentially different field than if its use is dictated by other factors such as flexibility of service, economy and speed. To deny the existence of this psychic "rubber urge" does not deny the motorcoach a place in city transportation, any more than it denies a place for subway service, elevated service and service with street-cars of various types. Had proper consideration been given to this psychological element in

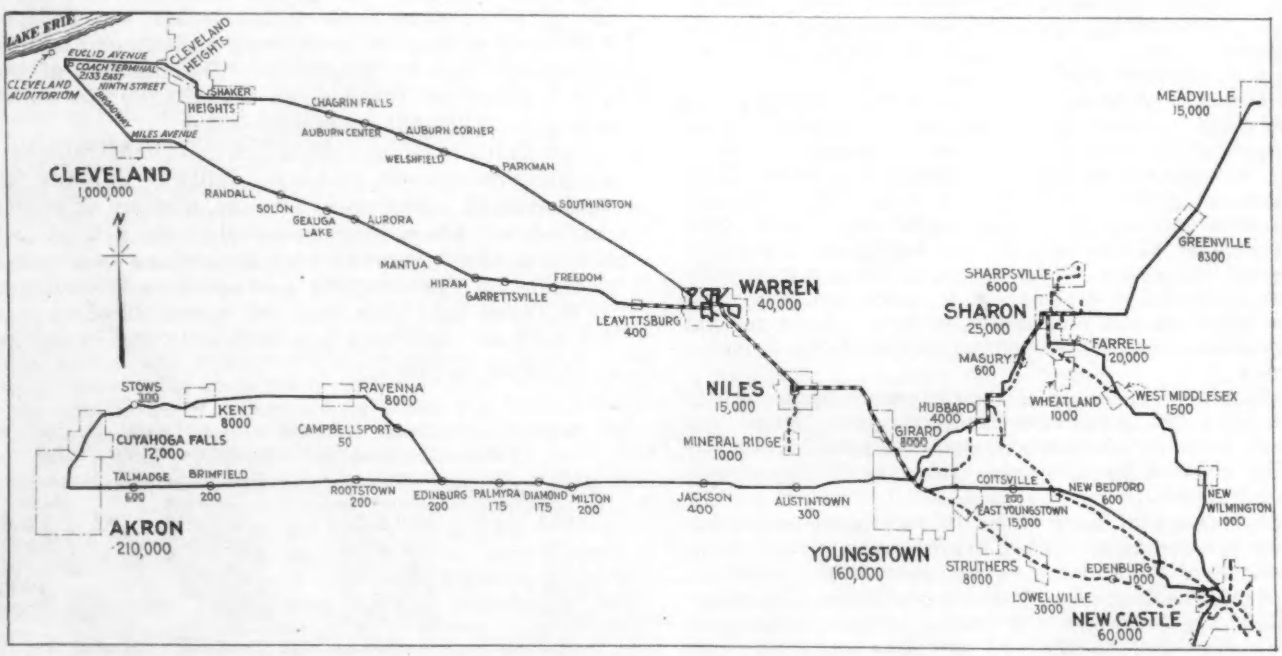

Fig. 1—Suburban and Interurban Motorcoach Lines of the Pennsylvania & Ohio Railways

The Route from Youngstown to Cleveland Is about 70 Miles Long, That from Youngstown to Akron about 50 Miles, and That from Youngstown to Meadville, Pa., about 70 Miles. Twenty-Nine Modern Motorcoaches Are Being Operated now in Regular Service over Nearly 400 Route-Miles in Express Service at a Higher Rate of Fare than Is Charged on the Company's Parallel Electric-Railway Lines, on Which 27 Cars Are Used on Regular Runs. Fourteen Motorcoaches Are Held in Reserve in Garages at Terminals and in Warren and Edinburg. The Youngstown-to-Cleveland Motorcoach Line Produces a Gross Operating Revenue of 44 Cents per Motorcoach Mile

the last few years, some very heavy investments might have been saved. Too much study cannot be given to the question of whether such an urge exists.

What Determines Public Riding-Habits

Inferences have been drawn hastily which ascribe to this intangible factor facts to which it never contributed. For example, in most cities of this Country the streets are laid out in checker-board arrangement, as is common in the Middle West; on one of these streets is a street-car line, and six blocks from this and parallel to it is another street-car line. Persons living on a street midway between the two car lines must walk three blocks to either car line. If a motorcoach line is operated on this midway street, the residents will patronize the motorcoach line. They are not influenced by the "rubber urge" but by the greater convenience of the motorcoach line. The same condition would exist if a street-car line were built down the midway street.

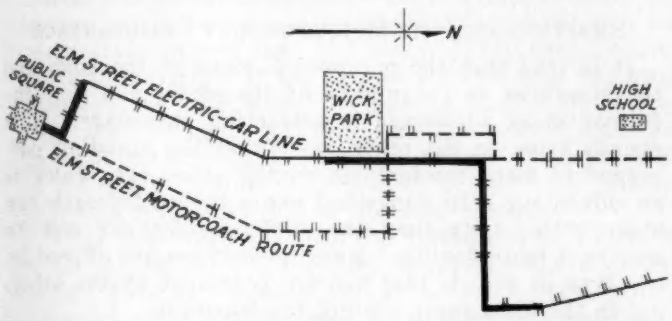

Fig. 2—Elm Street Electric-Car and Motorcoach Lines in Youngstown

The Car Line Is 2.6 Miles Long and the Motorcoach Route 2.5 Miles in Length. They Are Approximately Parallel for Much of Their Length, Serve the Same Territory and Give almost Identical Service at the Same Rate of Fare. They Carry almost Exactly the Same Number of Passengers per Month, but the Street-Cars Carry an Average of 16.1 Passengers per Trip and the Motorcoaches 14.8 Passengers. The Revenue per Car Mile Is 35.22 Cents and per Motorcoach Mile 34.67 Cents. Operating Cost per Car Mile Is 31 Cents and per Motorcoach Mile 26 Cents, Not Including Depreciation or other Reserves

Take as another example the street-car line on which the cars maintain a 10-min. headway. If motorcoaches are operated on this street over the same route as that traversed by the street-cars but splitting the headway of the street-cars, manifestly some of the public will ride on the coaches if similar service is given and the trip takes the same time. This again is merely a matter of convenience.

In some cases, in which the car tracks were worn-out and old, noisy and decrepit street-cars and a motorcoach line entered into competition, practically no customers used the decrepit utility but rode in the utility which, under the circumstances, provided them better service. This is an instance of the customer merely seeking personal comfort and convenience. The same transfer of patronage would have followed if a different street-railway company had laid new track in the same street and operated modern, comfortable, easy-riding street-cars.

Still other conditions exist that may lead to confusion of thought with respect to the "rubber urge." Thus, a given street-car route may cross at grade a number of railroads on which many train movements result in frequent delays to street-railway service. In the neighborhood may be some street that crosses over or under the railroad tracks and on which motorcoaches can be operated without the delays. In that event considerably more traffic would be given to the motorcoach line than to the street-car line. But, if a new street-railway were constructed in the street with the grade separation, it

Table 2—Service Given on Short Street-Car and Motorcoach Lines in Youngstown, Ohio, in October, 1926

	Miles Operated	Number of Trips
Street-Cars	22,236	7,846
Motorcoaches	21,878	8,568

would possess the same advantage over the original layout.

Again, a street-car line may have been built to provide transportation for a part of the city as originally laid out but in which such a shifting of population centers has occurred that a more direct route exists between the homes and places of work of the residents. Either a motorcoach or a street-railway line that followed the more direct route would attract more travel than the old street-railway.

After thus eliminating the factors that confuse the problem, let us face squarely the question: Does the motorcoach offer in itself an attraction that would cause more customers to use motorcoach service than a street-railway service under similar conditions? Leaving out of consideration for the present the question of relative expense of operation of the two methods of transportation, the answer to this query is very important in determining whether motorcoaches are a substitute for or a supplement to the electric-railway car in mass transportation.

Riders Seek Convenience, Not Vehicle Type

In Youngstown we have 8 motorcoach routes and 11 street-railway routes. The cash fare on all is 8 cents; seven tokens are issued for 50 cents, and a charge of 1 cent is made for a transfer. All routes are operated to the center of the city. Neither motorcoach not street-car shuttle routes are operated and duplicate service is not given. In general the motorcoach routes are extended into well-built-up parts of the city. The method of operating motorcoaches and street-cars is substantially the same.

As a result of 5 years' operation of the motorcoach lines, I do not hesitate to assert that little preference is shown by the citizens for either type of conveyance, but when a choice can be exercised, it usually is in favor of the street-car.

Comparison of Short-Line Operations

I wish now to cite a specific situation in which the conditions for a test of public preference are complete, I think, and in which the comparison is fair in every respect. Fig. 2 is a map of a street-car line and a motorcoach route in Youngstown that penetrate the same general territory. The car line is 2.6 miles in length and

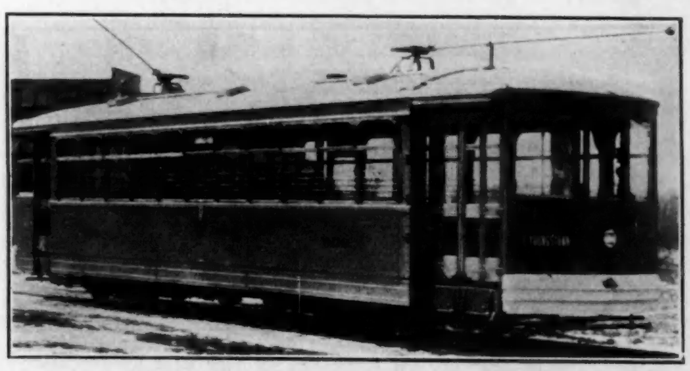

Fig. 3—Small Birney-Type 32-Passenger Car Operated on Elm Street Car-Line

These Cars Are Operated by One Man, Are 7 Years Old and Are Kept Clean. The Tracks Are Maintained in Good Average Condition

the motorcoach line 2.5 miles. They are three blocks apart for the greater part of their length but are separated by only one block for a distance of less than ½ mile and for the rest of the distance by five blocks. This motorcoach route was one of the first operated in Youngstown and service on it has been continuous for almost 5 years. The service given on these two lines in the month of October, 1926, was as shown in Table 2. The off-peak headway on both lines was 10 min. This required four street-cars and only three motorcoaches, as the service by coach was faster because a large part of the car line is single track, with sidings for passing. On the other hand, only one tripper car was used against three tripper coaches. The vehicles operated were small Birney street-cars, as shown in Fig. 3, that seat 32 passengers, and modern single-deck motorcoaches that seat 25, shown in Fig. 4. The cars had slat seats while the coaches were equipped with leather-upholstered seats. The car track would be regarded as fair average city-track.

With these two lines operating under nearly identical conditions, the traffic and revenue for the month of October, 1926, were also nearly identical, as shown in Table 3. The average number of passengers carried per one-way trip was 16.1 on the car line and 14.8 on the motorcoach line. This is a very high average load-factor for a 25-passenger motorcoach, as it is 60 per cent of the total number of seats offered. The car's load-factor also is high, as it is 50 per cent of the total seats offered, but this lesser loading makes it evident that more passengers secured seats on the cars than on the motorcoaches.

No physical obstacles to the operation of either the cars or the motorcoaches exist on either of these routes except that much of the car line is single track. A railroad crossing just outside the public square delays both motorcoaches and cars impartially. Rolling-stock of both types is fairly new; the street-cars are 7 years old and the motorcoaches from 1 to 4 years old. All are clean, the schedules are well maintained, cars and motorcoaches are operated with one man each and the men wear almost identical uniforms and badges and are well trained in courtesy and merchandising practices.

I believe that this exhibit should indicate to any unbiased and impartial observer who is interested only in determining intelligently the best tools for mass transportation, that the motorcoach has no inherent attraction that would influence its use by a prospective passenger in preference to using his own automobile and that would not apply equally in every respect to the street-car. The example given is confirmatory of our entire experience in this class of operation and also confirms the unbiased

Fig. 4—Type of Motorcoach Operated on the Elm Street Route
These Coaches Seat 25 Passengers and Are from 1 to 4 Years Old. The Single Operator Is Dressed in a Uniform Identical with That Worn by the Street-Car Operator. This Is a Better Transportation Medium on a 2½-Mile Route than the Street-Car as Regards the Operating Company's Interest

TABLE 3—TRAFFIC AND REVENUE OF SHORT LINES IN OCTOBER, 1926

	Total Passengers	Transfer Passengers	Revenue
Street-Cars	126,355	23,331	$7,833.40
Motorcoaches	127,103	23,933	7,585.08

observations of other men who are intensely interested in the transportation industry and are trying to define the field for the motorcoach. Clinton D. Smith, general manager of the Beaver Valley Traction Co., replying to a question on this subject in a questionnaire a few days ago, gave his conclusion as follows:

> Relative to preference of motorcoach service to street-cars, we are inclined to believe, in our case, that there is greater riding-habit on the street car than on the motorcoach. The motorcoach, all in all, is not as comfortable a riding vehicle as the street-car.

This was virtually the unanimous opinion of those to whom the questionnaire was sent.

Smaller Size Puts Motorcoach at Disadvantage

It is true that the motorcoach loads at the curb and the street-car in the middle of the street and that the former is an advantage in attracting patronage. It is equally true, on the other hand, that the standing passenger is more comfortable on the street-car, which is an advantage. In congested areas the motorcoach can make better time than the surface street-car and its service is more flexible. Many advantages are offered by one type of vehicle that are not possessed by the other, but in the main these are not fundamental.

One basic, serious and important distinction between the motorcoach and the street-car, however, that sharply limits the use of the former at the present time as an economic substitute for the street-car in mass transportation, is the difference in size. Two major conditions differentiate mass-transportation in America absolutely from that in any other country. First, public transportation in every city of the United States is conducted on a flat fare, that is, the fare per ride is the same regardless of the distance. This has been the practice for so many years that, as a measure of practical expediency, it may be said that it is impossible to change or uproot it.

Second, the maximum capacity of the vehicle is, with very few exceptions, used only once on a single trip. In the United States the growth of the cities has been outward in every practicable direction from the nucleus first established. As a result, whether one goes to Cleveland, Chicago, Kansas City, Omaha, Dallas, Houston or Los Angeles, he will find that the intermediate traffic is very light. In the morning the workers ride from their homes to the stores and offices and in the evening they ride in the reverse direction. During the day the passengers ride from the home to the theaters, shops and stores and then return home. Thus, the maximum capacity of the vehicle on any trip is in use but once. Only elementary arithmetic is required, therefore, to ascertain the earning capacity of any vehicle on at least 95 per cent of the trips in cities of the United States.

Factors That Definitely Limit Earning Capacity

The vehicles of any public-transportation system must be operated 18 hr. per day, and even in the peak hours the greatest traffic is in only one direction. Between the peak hours of the morning and afternoon, and throughout the period when the vehicles are moving at night, the traffic is relatively light. Therefore, with any public-transportation utility, we find that, for the total move-

ments in the entire 18-hr. transportation period, not as many passengers are carried as the number of seats offered. The load factor of such a utility is the ratio of passengers carried on all trips to the seats offered on all trips. Such a load factor for all the cities of the United States is not greater than 40 per cent.

If the seating capacity of any public-transportation vehicle is multiplied by the load factor to be expected and that product is multiplied by the average rate of fare, the probable earnings of such a vehicle on a single trip can be ascertained. If this sum is then divided by the number of miles the vehicle is operated on such a trip, the quotient is the earnings per mile. A general figure of probable earnings per mile with any given vehicle can be obtained by using average figures for the whole United States. The average fare per cash passenger today is 7.6 cents. The average fare, including transfer and free passengers and school children, is approximately 7 cents per passenger. Therefore, a 25-passenger motorcoach, with the usual load-factor of 40 per cent and the average rate of fare of 7 cents, should earn 70 cents per average trip. If the trip is 2 miles long the gross earnings are 35.0 cents per mile, and if 4 miles long they are 17.5 cents per mile. If the vehicle accommodates 50 passengers, the receipts will be \$1.40 per trip; if the trip is 2 miles they will be 70 cents per mile, or if it is 4 miles they will be 35 cents per mile.

Thus it is apparent that the distance over which the small vehicle can be operated profitably has a definite limit. It is not necessary to go very seriously into the question of operating costs to support this conclusion. With our 5-years operating experience with motorcoaches in city transportation, we are convinced that a fair figure for the operating cost of a single-deck 25-passenger motorcoach is 25 cents per mile, exclusive of reserve for depreciation, and 30 cents including all reserves. Our conviction regarding this is supported by all the operating figures to which we have had access.

Route Limit for Single-Deck Motorcoach

On the basis of these costs it is apparent that, using the general figures for the United States for load factor and average rate of fare, the operating radius of the single-deck motorcoach that seats 25 passengers is very little more than 2 miles. However, it must be conceded that the smaller the vehicle the larger will be the load factor. A minimum specific number of passengers carried on an average trip will contribute more to the load factor of a vehicle seating 25 than it will to a vehicle seating 50 passengers. If it is assumed that the load factor will reach 60 per cent under extremely favorable conditions in the case of the small vehicle, an average of 15 passengers will be carried on all one-way trips. At the average rate of fare, the receipts per trip would be \$1.05, which would produce an operating revenue of 35 cents per mile for a 3-mile trip. This is manifestly the absolute limit of distance over which a 25-passenger motorcoach can be operated at a profit.

TABLE 4—COMPARISON OF ELM STREET ELECTRIC-CAR AND MOTORCOACH OPERATIONS IN YOUNGSTOWN

Month of October, 1926

	Street-Car	Motorcoach
Length of Line, miles	2.65	2.50
Vehicle Miles	22,236.78	21,873.80
Trips Scheduled	7,746	8,400
Trips by Trippers	100	168
Cars for Base Schedule	4	3
Cars for Trippers Schedule	1	3
Maximum Number of Cars	5	6
Off-Peak Headway, min.	10	10
Peak Headway, min.	8	6
Time for Off-Peak Round-Trip, min.	40	30
Time for Peak Round-Trip, min.	40	36
Schedule Speed, m.p.h.	7.99	9.01
Gross Revenue	\$7,833.49	\$7,585.08
Revenue per Mile	\$0.3522	\$0.3467
Time Operated, hr.	2,781.05	2,427.58
Revenue per Hour	\$2.817	\$3.132
Total Passengers Carried	126,355	127,103
Transfer Passengers	23.531	23,933
Passengers Carried per Trip	16.10	14.83
Averages for 11 *Months of* 1926		
Operating Cost per Mile	\$0.3102	\$0.2598
Operating Cost per Hour	\$2.8219	\$2.4291

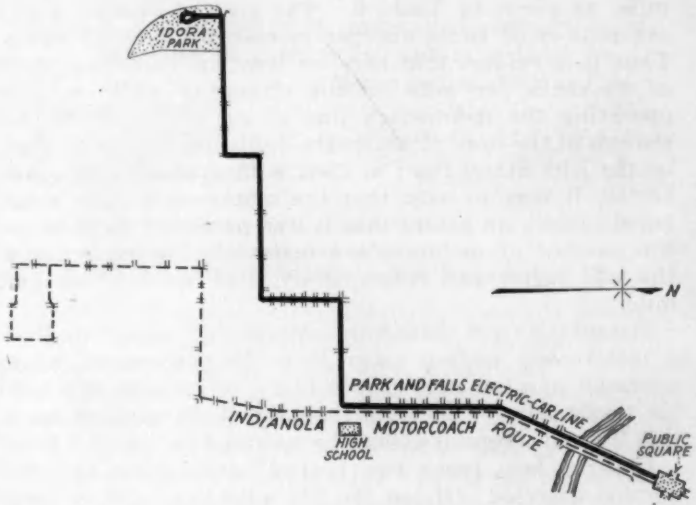

FIG. 5—IDORA PARK CAR-LINE AND INDIANOLA MOTORCOACH ROUTE IN YOUNGSTOWN

Both Lines Serve the Same General Territory. The Electric-Car Line Is 3.76 Miles Long, Has Double Track and 54-Passenger Cars Are Operated. The Motorcoach Line Is 3.55 Miles Long and 25-Passenger Vehicles Are Operated. The Average Motorcoach Load per Trip Is 14.82 Passengers, or about a 60-Per Cent Load-Factor. Revenue per Car Mile Is 42 Cents and per Motorcoach Mile Is Less than 26 Cents. Operating Cost per Car Mile Is 31 Cents and per Motorcoach Mile 26 Cents. The Cars Are Operated at a Profit of 11 Cents per Mile and the Motorcoaches at an Actual Loss

The operating figures on the Elm Street motorcoach and street-car lines in Youngstown, as given for comparison in Table 4, show that the revenue per street-car mile in October, 1926, was 35.22 cents and the revenue per motorcoach mile was 34.67 cents. The operating cost based on 11-months operation is 31 cents per car mile and practically 26 cents per motorcoach mile. In both cases, to make the comparison fair, no depreciation or other reserves or any return are included.

It is evident that, on a line of this length, the motorcoach is the better transportation medium as regards the earnings of the public utility that gives the service. Earnings per street-car mile might be increased, perhaps, by the use of larger street-cars, but only by decreasing the headway, and a decrease in headway probably would reduce the traffic.

How Earnings Compare on Longer Routes

Compare this situation with one in which a motorcoach line and a street-car line penetrate similar territory but in which the lines are much longer. Fig. 5 is an outline map of our Idora Park car line and our Indianola motorcoach line. The car line has double tracks, and modern cars that seat 54 passengers are used. The car line is 3.76 miles in length and the motorcoach line 3.55 miles. The motorcoaches are the same size as those used on the Elm Street motorcoach line and the average loading per trip is the same, that is, 14.82 passengers, almost 60 per cent of the seating capacity. Here the revenue is 42 cents per car mile and less than 26 cents per motorcoach

mile, as given in Table 5. The cost of operation per car mile is 31 cents and per motorcoach mile 26 cents. Thus it is evident that here we have an operating profit of 11 cents per mile on the street-car while we are operating the motorcoach line at an actual deficit, although in the item of traffic the Indianola line is as good as the Elm Street line; in fact, with a 60-per cent load-factor, it may be said that the motorcoaches are saturated to such an extent that it was necessary to increase the number of motorcoaches materially, which reduced the load factor and, consequently, also the earnings per mile.

Reasoning from these two examples, we would say that a motorcoach seating from 25 to 29 passengers, when operated on a line approximately 2½ miles long, is a better transportation medium than the street-car, but on a line 3½ miles long it cannot be operated except at a loss.

Observe how these two typical cases prove the deduction asserted. If, on the 2½-mile line, with a very large load-factor, we earn a revenue of 35 cents per mile, we should expect that on a 3½-mile line with the same rate of fare and with the same load-factor, the earnings per motorcoach mile would be reduced in exact proportion to the increase in length of line. This is exactly what has happened in these typical cases. Therefore, we have assumed, (*a*) that single-deck motorcoaches cannot be operated at a profit, even under the most favorable conditions of traffic, at a city rate of fare for a distance longer than 3 miles and (*b*) that the only change in the situation which will permit the operation of a single-deck vehicle for a longer distance at a profit will be a substantial increase in the seating capacity of the motorcoach. This increase must be substantial because it is entirely practicable to operate with one man street-cars that seat as many as 60 passengers.

If this increase in size of the motorcoach were brought about by an upper deck, the increase would be of no practical value in the usual American city. The double-deck motorcoach would require two men and the only hope of profitable operation at the customary city rate of fare lies in the elimination of the second man on every vehicle. The operating cost of a motorcoach with two men would be greater than the operating cost of a street-car operated by one man.

If we attempt to operate double-deck motorcoaches with one man we enter on extremely dangerous ground, that of liability for accidents. Twenty years ago the wheel height of the standard American street-car was 34 in.; at present it is 26 in. It has required the combined efforts of the industry for this period to lower the floor of our cars 4 in. for the purpose of reducing the accident hazard incidental to the carriage of the public in mass transportation. Arbitrarily adding 6 ft. to the height that any of the passengers must ascend to reach their seats, without the attention of a second man to regulate the movements of the vehicle, would be utterly impractical for most operating companies.

Practicable Urban Fields for Motorcoach

In view of the foregoing, the question may be asked, Where is the field in city transportation for the 16 or 21-passenger motorcoach? My answer is that no such field exists in city mass-transportation.

Where, then, in our cities can the 25 or 29-passenger motorcoach be used? I define the fields as follows:

(1) On routes not to exceed 3 miles where the traffic is dense

(2) On longer routes where, because of unusual conditions, intermediate traffic can be secured, as for instance, crosstown lines that intersect several street-railway or other public-transportation routes where passengers get on and off at different transfer points. Such traffic might readily build up the motorcoach earnings to such an extent as to render the use of the motorcoach feasible

(3) To provide service in territory that is not served by street-car lines in a city where the financial condition of the railway-company forbids the installation of additional trackage but where the rendering of some form of transportation service is necessary to round-out the function of the utility as a giver of transportation service in the community

(4) An even greater field than any of the foregoing exists for the use of this vehicle, I believe. This is for a special supplementary service to furnish unusual convenience at a much higher rate of fare. For example, in Pittsburgh several motorcoach routes are being operated from the suburbs to the heart of the city with a 25-cent fare and are meeting with marked success

I regard field (3) as providing opportunity for the most important present use of the motorcoach in urban transportation. All our own long motorcoach-lines are operated for this reason alone. They are operated at a loss to give the public, as a whole, transportation to all parts of the community.

Some factor of the equation must be changed if we are to increase the earnings per motorcoach-mile. The fare must be raised, the length of the trip reduced, the size of the vehicle increased, or the load factor increased. If the average rate of fare is tripled, either the length of haul can be tripled or the size of the vehicle reduced. It is feasible to operate a 21-passenger motorcoach at a 25-cent rate of fare where it would be impracticable to operate a 29 or 25-passenger motorcoach profitably at the standard rate of fare.

TABLE 5—COMPARISON OF IDORA PARK CAR-LINE AND INDIANOLA MOTORCOACH-LINE OPERATIONS

Month of October, 1926

	Street-Car	Motorcoach
Length of Line, miles	3.76	3.55
Length of Run to Loop, miles	2.75	—
Vehicle Miles	52,177.22	30,017
Trips to Park	8,664	8,224
Trips to Loop	7,414	—
Cars for Base Schedule		
Weekdays and Saturdays	12	7
Sundays	8	4
Cars for Trippers	—	—
Maximum Number of Cars	12	7
Off-Peak Headway to Park, min.	10	12
Off-Peak Headway to Loop. min.	5	—
Peak Headway to Park, min.	7	5
Peak Headway to Loop, min.	4	—
Off-Peak Round-Trip to Park, min.	45	36
Off-Peak Round-Trip to Loop, min.	35	—
Peak Round-Trip to Park, min.	46	38
Peak Round-Trip to Loop, min.	38	—
Schedule Speed, m.p.h.	9.67	10.73
Gross Revenue	$21,944.90	$7,709.90
Revenue per Mile	$0.4205	$0.2568
Time Operated, hr.	5,397.37	2,796.54
Revenue per Hour	$4.065	$2.756
Total Passengers Carried	359,476	121,937
Transfer Passengers Carried	66,412	17,521
Passengers Carried per Trip	22.35	14.82
Averages for 11 Months of 1926		
Operating Cost per Mile	$0.3102	$0.2598
Operating Cost per Hour	$2.8219	$2.4219

Chance for High-Fare Special Service

While the American public is vigorously opposed to a general increase of fare, no reason exists for objection to a higher fare for specialized service if such service does not impair the service given at the normal rate of fare. This specialized service cannot be given by street-car, as one condition of such service would be a high average rate of speed, and an express street-car service could not be run on the same tracks as the frequent-stop service. Moreover the public would not permit the laying of tracks in the street to serve only a small percentage of the population.

The history of transportation in all American cities shows that, although the community as a whole may fight to the last extremity for a low rate of fare, each community has a certain class that pays little attention to the cost of transportation so long as such transportation is quick and comfortable. The residents in this class are at present using their private automobiles to go to and from their places of business and are paying, not only for the depreciation, upkeep and operation of these cars, but a substantial sum to house them in garages when they have reached their destinations.

The modern motorcoach with its high average rate of speed, which would automatically be made still higher by limiting the number of passengers carried to the seating capacity and keeping the vehicle within reasonable limits of size, would meet exactly the needs of this class of citizen and by the collection of a fare of approximately 25 cents per person would be made a profitable transportation medium. Almost every city in the United States with a population of 150,000 could well support such a supplementary service and the demand for vehicles for this service would furnish to the motorcoach builders a more stable market than the attempt to force into mass transportation at standard rates of fare vehicles that are wholly impractical to operate profitably.

This statement should be amplified to a certain extent. In many places in the United States the conditions are such that even if the street-railway company were financially able to put down permanent tracks under conditions such as I have described, a loss of money would result notwithstanding the higher earnings of the street-car. And if money is lost in operating either motorcoaches or street-cars, the investment in motorcoaches is so much less than the investment in street-cars that the use of the former naturally is dictated.

I believe that by intelligently working-out the best use of the motorcoach we shall enlarge its ultimate use. If an attempt had been made in Youngstown merely to parallel street-railway routes with motorcoach routes, the investment in the motorcoaches would have been lost and our company would have been crippled in its ability to buy either street-cars or motorcoaches. But as a result of the effort to coordinate motorcoach service and street-car service, using each class of service where it is best suited to the conditions, we are now operating nearly as many motorcoaches as street-cars, the transportation situation has been improved and our motorcoach operation is self-sustaining. Surely this is a vindication of the policy of coordination rather than substitution.

In scarcely a city in this Country have sufficient street-railway lines been built in recent years to extend service into newer portions of the city. In almost all of these cities additional short motorcoach routes can be operated to sections now served only inadequately by street-railway lines, and every city of more than 150,000 inhabitants presents a field for specialized superior motorcoach-transportation at a higher rate of fare.

TABLE 6—COMPARISON OF INTERURBAN MOTORCOACH AND ELECTRIC-CAR SERVICES FOR THE YEAR 1926

	Motorcoaches	Electric Cars
Number Operated	29	27
Mileage Operated	1,910,940.58	1,743,553.10
Gross Revenue	$584,116.54	$661,943.73
Revenue per Mile	$0.305	$0.382

Great Suburban and Interurban Field

The field of suburban and interurban service presents a great future for the motorcoach. The operating company is not limited by a flat fare; every ride is a zone ride. The territory in which interurban railways never were built is much greater than the unfilled field in cities. Since the ratio of initial investment to the number of passengers carried is much less for the motorcoach than for the street-car, it is possible to operate motorcoach lines where it was impossible to operate any form of transportation that requires a fixed investment in any structures. Therefore the communities that lack adequate public-transportation connection with other communities which are natural markets, natural sources of supply or in which there are other community interests are rapidly being connected by motorcoach lines.

Where interurban railways have been built the motorcoach can be used by the railway companies in an intensive development of their territory such as was never possible without the motorcoach. Prior to 1922 our own company operated approximately 60 route-miles of suburban and interurban railway. It is now operating motorcoaches on nearly 400 route-miles. A comparison of our present interurban operation by motorcoaches and street-cars is given in Table 6.

The number of motorcoaches and street-cars shown is the number required for regular runs. We own 29 modern interurban cars and 43 interurban motorcoaches of the type shown in Fig. 6. The motorcoach service, which parallels the interurban lines, is a high-class express service and is operated at a higher rate of fare than the street-railway cars, which carry heavy industrial loads that could not be handled easily by the motorcoaches with their smaller seating-capacity. The connections of Youngstown with Cleveland, Akron and Meadville are natural transportation connections which it would not have been financially possible to establish by building interurban railways in recent years. Thus it is apparent that the use of the motorcoach has enabled us not only to give a more comprehensive service to points to which we already extended service but to extend our accommodations for the benefit of the public.

Fig. 6—Types of Motorcoach Operated on Interurban Routes
The Gross Operating-Revenue of These Motorcoaches on the Youngstown-to-Cleveland Routes Is 44 Cents per Mile. Depreciation Is now Figured on a 5-Year Basis. No Trip Has Ever Been Annulled on Account of Bad Weather or Road Conditions. The Vehicles Have Been Operated in Wintry Months When Operating Expenses Were More than Double the Revenue Obtained

Interurban Motorcoach Facilities Provided

We maintain complete and adequate terminal facilities in the larger cities for our main interurban motorcoach lines, which are shown in Fig. 1. Maintenance of a modern waiting room in the heart of such cities as Cleveland, Youngstown and Akron represents a heavy expense but we feel that we cannot offer our facilities as a real public service without extending all necessary conveniences to passengers in their use of the service. We also maintain depot arrangements in all the smaller communities through which our routes pass. All the routes are marked with zone markers and all stations are equipped with electric signs. Garages are maintained in Youngstown, Warren and Cleveland on our line from Youngstown to Cleveland and reserve vehicles are held in them to assure reliability of service. On the Youngstown-to-Akron line we also maintain garages at the terminals and at Edinburg, an intermediate point. We never have annulled a trip on account of ice, snow, fog or road conditions. This interurban service has been operated throughout winter months when the operating expenses were more than double the revenue, as we have felt that when it has been established definitely in the public mind that motorcoach transportation is thoroughly dependable, the public will feel as confident in undertaking a trip in zero weather as in midsummer.

That this hope is justified is indicated by the fact that the Youngstown-to-Cleveland line produces a gross operating revenue of 44 cents per motorcoach mile, which is the highest revenue per mile for either electric car or motorcoach in our entire operation. However, the operating expense of these interurban lines, due to the cost of terminal facilities, the elaborate arrangements made for maintaining schedules, and the high class of maintenance upon which we insist, is far higher than any figure that I have heard of or seen quoted by proponents of motorcoach operation.

Maintenance Increases Steadily with Age

In the first 3 years of motorcoach operation we charged off depreciation on the equipment at the rate of 25 per cent per year. In January, 1926, the condition of the original vehicles was such as to indicate that the assumed life of 4 years was too short and the basis of depreciation was changed to 5 years.

Our experience has been that maintenance expenses increase steadily throughout the life of the motorcoach when upkeep is maintained at the same standard. Many reports of motorcoach operation that indicate handsome profits tend to deceive promoters of motorcoach service, as they are based on a first year's operation before maintenance costs become heavy.

Operating expenses of the Youngstown Municipal Railway by years are given in Table 7. If motorcoaches were to be depreciated on a 4-year basis, I believe depreciation should be charged off as follows: first year, 40 per cent; second year, 30 per cent; third year, 20 per cent; and fourth year 10 per cent. If depreciation is included as part of the operating expenses, the operating expenses would be practically uniform throughout the period.

Brakes Cause Most Delay and Expense

As a result of our experience I should like to submit a few thoughts to the motorcoach builders. Their engineers seem to be greatly concerned with improving the design of the powerplant, but in our operation the maintenance of the engines never has been a major problem. One of our principal causes of worry is brakes, which are responsible for the largest number of interruptions to schedule and the largest expenditure of time in maintenance. We have no vehicle in which we believe that the brake problem has been solved. Brakes require too frequent adjustment and too much time for relining. Air-brakes have introduced another serious problem in the excessive wear of tires.

The chassis builder does not seem to be concerned about the time lost in filling fuel tanks, which requires from 10 to 15 min. on a large percentage of our motorcoaches due to the use of flat filling-pipes.

The State law in Ohio requires the use of accurate speedometers, but we never have had good results from speedometers themselves, nor from adapters or speedometer drives. As chairman of the Committee on Bus Operation of the Transportation and Traffic Division of the American Electric Railway Association, I find that this complaint is general throughout the industry and have been asked to take up the subject with the equipment manufacturers in an endeavor to obtain some dependable and satisfactory means of ascertaining the speed of our vehicles.

TABLE 7—OPERATING COST IN CENTS PER MOTORCOACH MILE OF YOUNGSTOWN SERVICE FOR 5 YEARS

	Last 4 Mo. of 1922	1923	1924	1925	First 10 Mo. of 1926
Equipment					
Repairs to Buildings	0.36	0.11	0.10	0.05	0.02
Superintendence	0.01	0.20	0.27	0.31	0.29
Repairs to Chassis	1.51	1.52	2.32	2.63	3.86
Repairs to Bodies	0.09	0.25	0.22	0.34	0.40
Tire Repairs and Renewals[2]	0.03	0.83	1.59	1.66	1.56
Accessories	0.31	0.29	0.29	0.39	0.00
Shop Expenses	0.37	0.12	0.07	0.08	0.02
Total Equipment Expenses	2.63	3.21	4.76	5.46	6.15
Conducting Transportation					
Superintendence[3]	0.00	1.03	1.29	1.28	1.16
Chauffeurs' Wages	6.05	6.34	6.94	6.73	6.83
Miscellaneous Service expense	0.23	0.12	0.31	0.22	0.24
Garage Employes' Wages	1.65	1.57	2.19	2.29	1.80
Garage Expenses	0.18	0.17	0.24	0.29	0.96
Gasoline	2.89	3.34	3.39	3.71	3.55
Lubrication	0.54	0.62	0.51	0.37	0.35
Miscellaneous Transportation Expense	0.28	0.28	0.32	0.45	0.59
Total Cost of Conducting Transportation	11.83	13.47	15.19	15.34	15.48
Advertising	0.00	0.01	0.00	0.00	0.00
General and Miscellaneous					
General Officers' Salaries	0.00	0.29	0.27	0.24	0.19
General Office Clerks' Salaries	0.00	0.15	0.14	0.15	0.14
Office Supplies and Expenses	0.00	0.10	0.13	0.10	0.05
Miscellaneous General Expenses	0.05	0.20	0.26	0.32	0.24
Liability Insurance	1.33	1.92	2.23	1.72	2.41
Fire Insurance	0.08	0.10	0.28	0.23	
Stationery and Printing	0.02	0.01	0.02	0.02	0.03
Stores Expense	0.00	0.00	0.00	0.00	0.04
Rental of Equipment	0.00	0.18	0.01	0.09	0.00
Rental of Garage	0.55	0.47	0.46	0.39	0.79
Total General and Miscellaneous	2.03	3.42	3.80	3.26	3.89
Street Railway Commissioner's Salary and Expenses	0.00	0.00	0.26	0.28	0.29
Total Operating Expenses	16.49	20.11	24.01	24.34	25.81
Earnings	25.20	24.90	29.40	29.39	31.01
Operating Net	8.71	4.79	5.39	5.05	5.20
Taxes	0.65	0.46	0.97	0.86	0.66
Depreciation, at 25 Per Cent per Year	2.31	2.98	4.22	3.93	2.83
Net	5.75	1.35	0.20	0.26	1.71
Fixed Charges, 8 Per Cent on Investment	0.77	1.01	1.00	0.96	0.92
Surplus or Deficit	4.98[b]	0.34[b]	0.80[c]	0.70[c]	0.79[b]
Cost of Service	20.22	24.56	30.20	30.09	30.22

[2] Guaranteed by supplier.
[3] Including dispatchers' and street men's wages.
[b] Surplus.
[c] Deficit.

Great developments have been made in increasing the strength of such parts as frames, driving-spindles and propeller-shafts that take the stresses in these heavy vehicles, but in our experience no unit that we operate possesses excess strength. We do not believe that aluminum castings should be used in any chassis part that undergoes stress. We have had several cases of serious near-accidents due to breaking of the aluminum spiders on steering-wheels.

Inadequate Mufflers Annoy the Public

It is necessary for a company that operates motorcoaches to preserve public good-will, yet more friction has developed between our company and the public because of inadequate mufflers than from any other cause. Only one make of vehicle that we have used is free from complaint on this ground. Several drivers have been arrested in recent months for operating with open cut-outs although our motorcoaches have no cut-outs. We have been compelled to detour our vehicles around hospitals and schools because of the complaints of noise. One of the chief causes of complaints against street-railway service has been the noise produced by the cars. Vehicles that run on rubber tires present an opportunity to eliminate excessive noise, yet it seems impossible after years of motorcoach engineering to have the engineering branch of the industry give serious attention to this important matter.

Too little attention is given in motorcoach design to safety considerations. Designs have been brought out frequently in which it is impossible for the driver to see his right front fender or the right-hand curb except at some distance ahead of the vehicle. In our operation every other consideration is secondary to safety and we would never feel that we were discharging our duty to the public and to our stockholders if we operated a vehicle in which the driver was hopelessly handicapped as regards safe operation.

Not enough consideration has been given to the ability to use chains when the streets and roads are icy. I have heard it contended that certain vehicles do not need chains. We operate many different standard types of vehicle and on the heavy grades of our interurban lines, under icy conditions that have prevailed this winter, it was impossible on a number of days to complete the trip without putting on chains.

These matters are not of fundamental importance and will be taken care of eventually. The modern motorcoach is a substantial, sturdy and useful vehicle. We operate 125 in all, which represent an investment of nearly $1,000,000. The garages represent an investment of $200,000, and parts and auxiliary property probably $150,000 more.

Prior to our use of the motorcoach in Youngstown not a single first-class motorcoach was operated in the city. We have purchased from time to time approximately eight interurban operations. Only two of these operating companies owned any rolling-stock that we would be willing to place in public service.

Service has been increased substantially on every line that we have bought. We have cooperated with every independent motorcoach operation in our territory. In Youngstown, Warren and Sharon we provide terminal facilities for all interurban motorcoach-operations and for a large part of the operation out of Cleveland. In cooperation with the leading independent lines of our territory, we sell an interchangeable mileage-book that enables the traveling public to ride indiscriminately over the routes in northeastern Ohio. We sell through tickets from Cleveland to many different points over our own lines part of the way and over independent lines part of the way. We have joint-ticket arrangements with at least half a dozen independent lines that have no connection whatever with any electric-railway property. We advertise their service in our schedules and in many cases extend the assistance of our schedule and traffic departments to these independent lines to help them arrange their schedules and tariffs to best advantage and to assist them in complying with the rather technical requirements of the Public Utilities Commission.

If our history and attitude is in any way typical of that of the electric-railway industry in general, certainly every reason exists for cooperation between the electric-railway industry and the motorcoach industry.

THE DISCUSSION

Adrian Hughes[4]:—Had I read Mr. Graham's paper before accepting the invitation to come here and discuss it, I think I should have been much inclined to decline, because he has covered the use of motorcoaches for mass transportation so thoroughly. There seems to be little I can add, nor does there seem to be any chance to take issue with him. He has gone right to the heart of this question, which is so important to both the builder and the user of motorcoaches. His paper is a real contribution to the subject and I am glad to have had the opportunity to hear him.

The United Railways & Electric Co. of Baltimore, with which I have been associated for a number of years, has been operating motorcoaches since 1915, and was, I believe, the first railway company to take advantage of the new transportation vehicle. The object was to meet jitney competition. The operation was continued first, because we could not let go of it, and later, because the motorcoach was found to have a useful field even for an urban-railway operation in a large city.

The operations of the railway company in Baltimore have always been confined to the metropolitan area of Baltimore and its vicinity. It never operated interurban lines and consequently does not operate interurban motorcoach routes. Unlike the North and Middle West, comparatively little opportunity has existed for interurban operation in Maryland. The railways system operates 1200 street-cars in the peak hour on 35 routes over 412 miles of track and, through the Baltimore Coach Co., recently known as the Baltimore Transit Co., owns 80 motorcoaches and operates 11 routes of an aggregate length of 47 miles.

In 1926 the motorcoach revenue was $708,000, of which $600,000 was from operation on the regular routes and $108,000 was from special motorcoach-operation. The total number of passengers carried on the motorcoaches was a little more than 8,000,000; the total carried on street-cars was 362,800,000. The situation in Baltimore, therefore, is somewhat different from Mr. Graham's, but the same principles are involved and about the same conclusions are indicated.

I was asked to take charge of the motorcoach operation about 2 years ago to study where we could and should use motorcoaches. Like Mr. Graham, I have felt that, to the operating man, the design and even the maintenance of motorcoaches are secondary to the big problem of the proper application of these vehicles to the transportation needs of the public. It has, therefore, been necessary to make an intensive study and analysis, first, of our own operations and then of operations on other

[4] M.S.A.E.—Superintendent of motorcoach transportation, United Railways & Electric Co., Baltimore.

properties, both urban and interurban. I am not prepared to say that the answer has been found, but some very interesting things about the application of motorcoaches to transportation have been brought out. Like everyone else who is interested, I am anxious to find the answer and discussions like this will produce it. The solution is of first importance to railway and railroad companies, to the independent operator and to the builder.

Motorcoach Operation a Big Economic Problem

So far as electric-railway companies are concerned, no prejudice exists against the motorcoach at this time. Prejudice grew from the unfair conditions of the independent competition when it first developed. As Mr. Graham has said, the only serious competition for any transportation agency, whether it is using cars, motorcoaches or both, is the private automobile.

The application of the motorcoach is a matter of economics and of judgment in determining when the economics of the situation justify operation and when they do not. Street-railway companies often are handicapped by motorcoach operations that parallel their lines and that they were forced to take over and cannot now discontinue, and that, because of the length of the route and the low fare, may operate at a loss while at the same time they take revenue from the street-car routes. Money spent on such a line could be spent to advantage in operating new routes where the car lines are far apart or where the city is expanding into new territory.

I doubt if much of a field for motorcoach operation exists in large cities over established street-car routes. The motorcoach has an application for connecting lines and for feeder lines. In the large city it is probable that it always will be a comparatively small part of the operation; however, it is a very important part, and in Baltimore we consider the study of the application of the motorcoach one of the major problems of the railway industry.

It is sometimes hard to determine when the service is justified even as a feeder line. Because the individual can run two or three motorcoaches from the end of a car-line, it does not follow that such operation is economically justified. He might be able to eke an existence out of such an operation when, for the transportation company, it would represent a losing proposition, not because it would cost more to operate but primarily because the transportation company would be required to give a much higher class of service and often at a lower fare.

It is easy to fill the motorcoach on the feeder lines during the rush hour, but during the rest of the day the traffic often is not sufficient to pay for the gasoline, oil and maintenance. The choice then lies between running frequent trips at a loss or running only a few trips in the rush hour. In the latter case the cost for such an operation, instead of being on the average rate of 30 cents or so per motorcoach mile for the entire operation, may be 50 or 60 cents, or even more. This illustrates the importance of investigating the cost of each route separately from the operation as a whole. It is essential to know with a reasonable degree of accuracy the cost of each route as well as the revenue. It is necessary to know this in the operation of the existing routes to know how to decide on new routes. It is not very difficult or complicated to find these data. I have worked out a method[5] of prorating costs that has been found satisfactory and practicable. I believe that the success of an operation depends to a certain extent on the proper investigation of the costs in some such way as this.

Such a knowledge of the various parts of the operation will often prevent the starting of a new line where it is not justified. It is just as harmful to the development of the motorcoach for transportation purposes to try to apply this form of transportation where it is not justified as it is to neglect it where it should be used.

It was important to segregate the cost by routes in Baltimore because our motorcoach operation is extremely varied. We are operating lines that parallel and compete with our street-car lines. We are operating motorcoach lines that intersect and transfer to street-car lines at the railway fare. We are operating motorcoach feeder-lines, in some cases at the railway fare with a street-car transfer and in other cases at an additional fare. We are also operating a considerable and growing special motorcoach-service. This last seems to offer a considerable field for the use of motorcoaches in large cities. Such service is entirely different from usual mass-transportation; it is a special service and a special rate can be obtained for it.

Street-Cars Best in Large Cities

From our experience I do not see much indication that motorcoaches will ever be on a par with street-car transportation in large cities. A transportation system is essential in any city of size; the automobile cannot take care of traffic in a large city due to the congestion. At present it appears to us that the street-car is best for this purpose, because of its economy of operation and because, due to the traffic congestion, a large unit must be used. Even the double-deck motorcoaches that we operate do not seem to solve this problem as compared with street-cars. To compare a double-deck motorcoach for mass transportation with a single-deck street-car is to compare two means that are essentially different. A double-deck street-car is fully as practical structurally as a double-deck motorcoach but the same objection applies to both; that is, the delay in loading and unloading. One of the primary questions at present in mass transportation in large cities is speed, and time spent in loading and unloading has an important bearing on the running time.

Exaggerated Statements Do Not Help Solve Problem

Speaking of the incorrect application of the motorcoach in transportation service brings to mind an article in the Baltimore *Evening Sun* of Feb. 16, 1927, which attributed to N. A. Hawkins, former sales manager for the Ford Motor Co., the statement that

> Trucks will soon put railroads out of the short-haul business, both for passengers and freight. Shippers are just beginning to realize that commodities can be sent over short distances cheaper by truck than by rail. Passengers, too, are depending more and more on motor transportation, as it is more economical and takes one direct to destination without the additional taxi fare from the railroad station. Buses will soon be on a par with trolley transportation in every city of size in the Country.

This statement obviously is incorrect; nevertheless similar statements appear frequently in the sections of the newspapers devoted to automobile news from men prominent in the automotive industry. I do not believe that such statements contribute to the solving of this important problem of the application of automotive vehicles to the transportation of passengers and freight. They are at variance with the kind of discussion we are having here tonight. To any one who is familiar with

[5] See *Bus Transportation*, November, 1926, p. 617.

the transportation business, they are exaggerated and unsound, but they mislead the public and are rendering the solution of the problem more difficult for both the users and the builders.

Motorcoach Saves Street-Railway Losses

We must know where not to use motorcoaches to determine where they can be used. Each case must be considered on its own merits, even in a large city. We must apply an analysis of the cost of a similar operation to each individual project and work out just what revenue and operating cost may be expected, and in that way justify a decision for or against putting on a motorcoach operation.

In making such an analysis of costs we have divided our operation, which shows an annual deficit of about $30,000, into several groups of lines. One group, which operates in competition with or independently of our railway system, shows a profit of about $20,000; the remaining group, which is a part of the railway system and operates at the railway fare with transfers to a great extent, shows a deficit of more than $50,000. By analyzing each of these latter lines separately to ascertain the operating cost of each line and then comparing that cost with the cost of giving the same service with street-cars, we have found an indicated saving of more than $400,000 a year by the use of motorcoaches. From that point of view our motorcoach operation is very satisfactory. It should be borne in mind, however, that if the motorcoach had not been developed, some of these lines at least, and perhaps many of them, would not have been put on with street-cars under present operating costs and rate of fare, hence the $400,000 is the maximum saving and not the true figure of what we are saving by motorcoach operation. Nevertheless, it shows that a real saving results where motorcoaches are applied correctly and is an indication of the value to us of our motorcoach operation. The motorcoach has a very useful application on the urban transportation-property.

Chairman R. E. Plimpton[6]:—We have a number of welcome guests this evening from another Metropolitan Section, the one connected with the American Electric Railway Association. This section has built up a membership of 1200 in less than 3 years. Will Mr. Quinn speak for his associates?

Walter J. Quinn[7]:—The Metropolitan Section of the American Electric Railway Association is a very recent organization and is made up of the representatives of the street-railways in this vicinity, including New Jersey. The membership has grown fast and great efforts are being made to double it. With the exception of the Public Service Railway Co. of New Jersey, not many of us are as yet actively engaged in motorcoach operation but many are trying to get in, as may be judged from the number of applications that have been made for franchises in New York City. Some time must elapse before we shall know which of us will be in a position later on to respond to an invitation to tell something about our operations.

Inner-Traffic Motorcoach-Zone Suggested

C. W. Stocks[8]:—Mr. Graham has presented well-developed arguments backed with his own experience to indicate what he believes can be expected of electric-railway companies in attempting to coordinate or supplement their rail services with motorcoaches in handling mass transportation in city service. He has stated frankly that in mass transportation he does not differentiate between a motorcoach and a street-car, and that street-cars are not operated when a motorcoach can be used more effectively. This idea has evidently been followed out in the cities of Sharon and New Castle, in Pennsylvania, and in Warren, Ohio, where the local trolley-lines have been replaced with motorcoaches. Presumably the change was made in the interest of economical operation, because in these cities there could not be the need for duplicate transportation-services such as those in Youngstown. Recognition may also have been given to the present demand of patrons for modern public-transportation facilities for different routes and to the fact that the motorcoach is best suited to furnish this service when investment is considered. Perhaps the street-cars and track were not in the condition he spoke of for Youngstown.

His statement and deductions that single-deck motorcoaches cannot be operated at a profit on routes more than 3 miles in length if the fare approximates the average electric-railway flat fare of 7.6 is not surprising. His argument, however, leads me to believe the motorcoach can be used in many cities to take care of what may be termed the inner traffic-zone, leaving the railway to operate the longer flat-fare city routes with cars of larger capacity than the present type of single-deck motorcoach. This inner zone can have a radius of 3 miles and the maximum length of haul or ride of 6 miles, for a single flat-fare of 8 cents plus a nominal transfer charge of 1 cent, making a total fare of 9 cents or 1½ cents per mile. Such a plan would offer wide use of the motorcoach in our American cities, not many of which have much of a population area beyond the 3-mile limit.

With a larger capacity single-deck motorcoach, which is possible even on a four-wheel chassis, and with consideration given to the investment required for railway operation, it is likely that the length of motorcoach route into new territory can be increased beyond the 3-mile limit if the traffic warrants, even at the average electric-railway flat rate of fare. However, it must be recognized that to hold the railway service profitable in the outer zone of our cities the street-cars must be operated the minimum number of miles to keep pace with the railway investment and such operations must be scheduled carefully. With a flat fare the problem becomes all the more serious if the long-haul traffic is not of sufficient density to give a fairly good load-factor.

An example of the need for vehicles of larger capacity to handle a similar traffic is presented by the motorcoach line operated to Jackson Heights in the Borough of Queens, New York City, by the Fifth Avenue Coach Co. This line started with 29-passenger single-deck motorcoaches but to make the operation a success vehicles of larger capacity, to operate at a flat fare of 10 cents, were substituted. A double-deck motorcoach of 55-passenger capacity was developed that could be operated over the Queensboro Bridge. The change has been beneficial from a revenue-producing viewpoint. This meets exactly the argument advanced by Mr. Graham for using trolley-cars on his lines that are more than 3 miles in length.

Short-Cut and Rush-Hour Service

Mr. Graham has overlooked what may be termed short-cut or bypass trips from large employment centers or factories at specific times of day. Here is an opportunity for traffic that can be handled readily with motorcoaches, for routes can be laid out to meet the needs of the patrons without having to carry them all through a

[6] M.S.A.E.—Associate editor, *Bus Transportation*, New York City.
[7] Electrical engineer, Third Avenue Railway Co., New York City.
[8] Editor, *Bus Transportation*, New York City.

central point and requiring them to transfer to other routes to reach their destinations.

Again the motorcoach seems suitable for special rush-hour routes, especially in city service with the flat fare and one-way traffic. It has long been the practice of transportation companies to give special morning and evening tripper service over special routes to tie-in parts of the city not reached by regular routes. This is a field that has not yet been touched to any great extent by motorcoach service as operated by the railway companies.

Special supplementary service at a higher rate of fare than is charged in mass-transportation service presents an opportunity not so much for a flat fare as for a zone system or mileage rate with the minimum higher than the mass-transportation rate. In this service each passenger is entitled to a seat, and the difficulties incidental to collecting zone fares from this number of passengers are no more serious than on short intercity runs. The troubles of the flat-fare system of rates should not be carried into this new form of service. Five cents per mile, either with fixed or variable zones and station stops could afford an attractive service. Care must be exercised in establishing such service, however. It is primarily a rush-hour service and should be extended only as conditions warrant. To operate it 18 hr. per day would indicate a lack of appreciation of the fact that in the evening and off-peak hours the private car now plays a most important part in local transportation in cities of normal size and that the taxicab becomes a factor in large cities. Then, too, such routes would not blanket a city until the service had proved popular. The thought here is to conserve profits from actual operation and not fritter them away in operation during light-traffic periods. This is a field for the small motorcoach of the parlor-car type, of 17 to 21-passenger capacity, as a developer of traffic and, as traffic grows, for the larger 25 and 29-passenger vehicles. Service of this type at a flat 25-cent fare is already in operation in the City of Washington, Pittsburgh and Kansas City, Mo., and in a modified form in Toronto.

In any transportation system each motorcoach route should nearly earn its cost of service, for unless this plan is followed the demands for extensions cannot be met. Where non-profitable routes are established, schedules need to be laid out to serve the greatest number of patrons. To say that all routes must be operated 18 hr. daily is unfair to the patrons of self-sustaining routes. It can mean only a higher rate of fare to them.

Profits Do Not Justify Laying Tracks

CHARLES M. MANLY[9]:—Would the figures on cost of electric-railway service be as favorable, Mr. Graham, if the railway lines had to be installed at the present cost of labor and materials or if extensions of electric lines were made at present costs?

R. N. GRAHAM:—In my opinion, they would not, in our city. Any possible profit that would be made from electric railways in our operation would not justify any company in laying the track.

MR. MANLY:—Would not your profit turn into a loss if you had to install those lines at the present cost of labor and materials?

MR. GRAHAM:—Any capital investment, whether it is in motorcoaches or street railways, is not an element of operating cost. Consider, for instance, the 3¾-mile car line and motorcoach line that were compared. The car line showed a profit of 11 cents per mile in operation and the motorcoach line a deficit; that is actual operating cost. Regardless of the original cost of the structure, the car line would still show a profit, but the profit would not be sufficient to justify putting the investment into the tracks. The profit would be the same regardless of the cost of the structure. The only operating expense that varies with the cost of the structure is depreciation.

MR. MANLY:—But depreciation goes up if the cost is higher.

MR. GRAHAM:—Yes, but the depreciation on the track structure is reckoned at 20 years, 5 per cent per year, and the mere increase of the item of depreciation would not wipe out an operating profit of 11 cents.

Our entire capital investment in Youngstown is approximately $4,000,000, and we make only 4 per cent return at the present time on the investment. If the investment were greater, our return would be less. So it is evident that if the city of Youngstown were without any transportation facilities today, no one would lay down street-car tracks, because the profit would not pay a return on the investment. More money could be made by putting the capital in the savings bank. Neither would there be a profit in the operation of motorcoaches to replace these street-car lines if the fare remained the same as it is today. With the street-car tracks in existence, however, the company is better off to continue to operate the street-cars, because the investment is already made.

Problem of Special-Fare Service

CHAIRMAN PLIMPTON:—The operation of special-service motorcoach lines, such as Mr. Stocks referred to as being operated in the City of Washington; Kansas City, Mo.; Pittsburgh; and to a certain extent in Toronto is very limited in its scope, it seems to me, and is rather unsound from a transportation point of view. If one tries to charge a flat fare, even though the fare is higher than the ruling fare on the local trolley-cars or motorcoaches in a place where the transportation haul is short, he will be confronted with the same problem of a wide divergence in the peak and the off-peak demand.

The usual idea is that this sort of service should provide a seat for every passenger, but, so far as I know, the only such lines that have made a success are operated on long runs along which several traffic centers exist and several passengers can be picked up on the trip for each seat. Unless this can be done, I cannot see wherein the 25-cent system has any advantage over the lower-fare system that carries standing passengers. The 25-cent lines I have seen are either carrying standing passengers or are not operating Sundays, as a rule, when there is little travel. I know of one line at least that had to shutdown in the summer because it was in a city where many of the people go away when the schools are closed. In another case a check was made of 130 trips during a day and it was found that on about 30 per cent of the trips only one or no passengers were carried. On the rush-hour trips standing passengers were carried.

Mr. Graham has said that the 25-cent service will pay in a city with a population of 160,000 or more. Youngstown is in this class. How many lines or motorcoaches can be operated there on the high-fare basis?

Some Attraction Must Be Offered Riders

MR. GRAHAM:—It is a simple matter of arithmetic. The factors are the fare, the load factor, the seating capacity, and the length of the trip. Anyone of these can be varied. It is known that the fare for all of the people cannot be increased, but the fare for some of the

[9] M.S.A.E.—Consulting engineer, New York City.

people can be increased. The question is, Can attraction enough be plucked out of the air to induce some of the people to ride? My judgment is that a city of 150,000 would support such a service. In our own experience we have practically the direct equivalent of this. We operate a street-car line between Youngstown and Warren. The fare is 30 cents. We also operate a motorcoach line at 50 cents. The latter operates faster and the number of passengers is limited to the seats provided. This service has been operated 4 years. We do not have the trouble of which you speak, because the passengers who are attracted by that sort of a ride are not customarily industrial riders; it appeals to the woman going shopping. Not every family has three or four automobiles, and even if she has an automobile, the woman may find this special service so satisfactory that she prefers it, as it saves her the trouble of finding a garage and all that sort of thing. It is necessary to provide a service that will attract the people. It is my opinion that a field exists for such a service.

GEORGE H. SCRAGG[10]:—In analyzing a particular operation many factors may exist that might vary Mr. Graham's figures somewhat. In different communities the frequency of service has a great value and an important effect on riding habit. Even if the fare is as low as the average fare Mr. Graham suggests, or lower, this low fare frequently affects riding habit sufficiently to bring-up the load factor in the off-peak hours. Our big problem in motorcoach operation is that we must take care of the peak-hour service, and undoubtedly the street-car has an advantage over the motorcoach at that period. Within a very short distance of New York City we have a 5-cent motorcoach operation over a route of about 6 miles that has a load factor of more than 100 per cent. Because of the 5-cent fare the public is using the coaches for five and six-block rides. This is a very enviable condition. The line, however, never would have been started if the particular local conditions had not been studied and if we had merely applied Mr. Graham's formula.

BRAKES IMPROVED FOR POWER OPERATION

H. D. HUKILL[11]:—The company with which I am connected was associated with the development of the street-railway industry long before the motorcoach was heard of. I want to compliment Mr. Graham on his temerity in coming before a roomful of automotive engineers as a representative of the street-railway business and telling the vehicle builders and the equipment manufacturers some of the things that are wrong with their equipment.

Mr. Graham criticized the excessive wear on tires caused by air-brakes. Since the air-brake equipment has been developed and adapted to the automotive vehicle, it has been found necessary in a number of cases to redesign the earlier and lighter types of foundation brake that were adopted for manual operation to make the brake rigging suitable to obtain the full benefits that are possible with power operation. It may safely be said, I believe, that the coordinated and intensive developments along these lines that have been made during the last several years by the axle and vehicle builders and the air-brake manufacturers have eliminated in present-day vehicles all causes for the trouble mentioned.

I should also like to say a few words regarding the special motorcoach-service in Pittsburgh, that was touched upon by Mr. Graham. I live in a district of Pittsburgh in which it is about a 15-min. walk to the nearest street-cars, which in turn require from 30 to 45 min. to reach the downtown section. It is, however, but a 2-min. walk to the motorcoach line on one of the main boulevards and the coaches take 20 min. to get downtown. About 90 per cent of the residents who live in that district always use the motorcoach, I think, even in preference to their private cars, because, with the motorcoach, the downtown parking problem, which is a serious one in Pittsburgh, is eliminated. They board the motorcoach near their doors and are deposited right at their destinations. They are willing to pay 25 cents, or I believe even more if a higher fare is necessary to make the special service a paying proposition for the street-railway company.

POWER BRAKES REQUIRE SPECIAL SHOES

CARL ABELL[12]:—Brake-linings were developed to meet certain known conditions imposed by mechanical braking, which means that they have an extremely high coefficient of friction. If a power-brake is used with a brake-lining that has such a high coefficient of friction, it is likely to ruin the tires. Furthermore, brake-lining of the fabric type is made of a material that insulates against heat. Friction develops heat, and that heat must be dissipated. If an air-brake connection is put on a small-diameter wheel and the brake-drum is close to the rim, a great quantity of heat will pass into the tire. In many cases the heat is sufficient to vulcanize the bead of the tire and blow-outs occur at the bead, which was almost unknown until air-brakes were applied to these heavy vehicles.

I have been working for the last 4 years with an organization that developed pioneer motorcoaches and that did most of the early experimental work on air-brake applications to them. We found very soon that the fabric lining was not suited to air-brakes. Air-brakes had been developed to permit the use of a certain definite type of metal shoe that could convey the heat away and that had a coefficient of friction which was suitable to use with the power-application of brakes. Largely through our efforts, in cooperation with the Westinghouse Air Brake Co., metal brake-shoes that have these two desirable features for use with the power-brake are being made by several axle companies.

[10] Jun. S.A.E.—Executive, motorcoach department, International Motor Co., New York City.

[11] M.S.A.E.—In charge of automotive division, Westinghouse Air Brake Co., Wilmerding, Pa.

[12] Publicity manager, American Car & Foundry Motors Co., New York City.

Addresses at the Mystery Session of the Annual Meeting

THE addresses delivered at the Mystery Session of the 1927 Annual Meeting by Past-Presidents and the incoming President for the year follow. Each spoke on a subject of his own selection, without knowledge of what the others were to talk about, and no announcement was made before the convening of the session as to the topics to be presented or the speakers; hence the "mystery." Several of the speakers corrected the manuscript of their remarks before the transcript was edited.

Mr. Bachman's address deals with the change in attitude of the steam and electric-railway interests toward the operation of motorcoaches and motor-trucks as common carriers. He maintains that these agencies are not in general competition with rail transportation but can be used by the railways as a valuable adjunct, and that the recognition of this by the railway systems is a valuable contribution to transportation economics. He cites the effect of the motor-vehicle upon the upbuilding of American communities, the congestion that has developed, and suggests that, in addition to measures now being studied to increase arterial facilities for traffic, it will become necessary in the relatively near future to decentralize marketing and shopping activities.

Mr. Vincent recites in a semi-humorous vein the progress of the industry in a long series of circles and calls upon the young engineer to exercise patience and fortitude in the face of repeated returns of the industry to principles long ago tried and forsaken. He recalls various examples of this traveling in circles or reversion to the primitive state of the art but says that the industry always continues to advance.

Mr. Crane makes a plea for the use by engineers of more imagination in their work and points to the breaking-down of the idea in this Country by Henry Ford that the automobile is a vehicle for sport or for use by the spendthrift as an example of the use of imagination and foresight. He points out that imagination divides the real engineer from the copyist and observes that the greatest commercial opportunity comes to the man who fills a long existing need before the public becomes conscious of this need.

Mr. Hunt shows how artificial restrictions, mainly of a legal nature, restrict the engineer, as the heavy tax on motor-vehicles in Europe has made the English and Continental light-cars what they are today. Labor regulations that attempt to restrict the use of certain tools or processes instead of being directed toward elimination of any evils that might exist in the specific processes are criticized, as is also the tendency of State authorities and others to specify what devices or designs shall be used, such as headlights, based upon guesses as to what they will do rather than upon past experience. Engineers are urged to use their influence in an endeavor to preserve the situation that has allowed the freedom of action in this Country which made possible the rapid development of the automotive industry.

Mr. Kettering's address deals briefly with the investigation of the President's Oil Conservation Board, the relation of our oil resources to fuel consumption by internal-combustion engines, the possibility of conversion of coal into liquid fuels, and the long line of development upon which we have started in the effort to produce engines that will give greater fuel economy.

RELATION OF HIGHWAY AND RAIL TRANSPORTATION

BY B. B. BACHMAN[1]

AT the time of the Semi-Annual Meeting of the Society in 1922 a somewhat new development was coming from the western coast. Manufacturers had started the business of building motorcoaches and the use of the motorcoach had steadily extended eastward. Also at that time we were close enough to the post-war period to have, possibly, a distorted idea of the place of the motor-truck in the transportation system of the Country. During and immediately after the war the congested condition of our railroads and the urgent demand for transportation developed the use of the truck in long-distance hauling. Moreover, we were entering a period of active concern with highway development; millions of dollars had been appropriated and were being spent in the construction of trunkline highways and a great deal of discussion arose as to whether these highways should be developed to suit local conditions and needs or be laid out to accommodate this incipient development of passenger and freight transportation. This discussion assumed an acrimonious phase in some of its aspects. Interests associated with highway transportation took one side and those associated with rail transportation took the other side.

Under these conditions I made the remark, as chairman of the session at the meeting, that,

> Except in the most isolated cases, competition between rail and highway transportation is most unlikely. I think this is almost universally true with regard to the transportation of goods and in the transportation of passengers. If we use our imagination we can trace what must be the development of the future.

The following January, at the Annual Dinner at the Hotel Pennsylvania, we had the good fortune to have Elisha Lee, vice-president of the Pennsylvania Railroad Co., as our principal speaker. The high point of his address, as I recall, presented the thought that new devices and new methods have never in the history of the world totally displaced old forms. Exceptions to that

[1] M.S.A.E.—Engineer, Autocar Co., Ardmore, Pa.

generality may come to mind, but in transportation, communication and many industrial fields, I think it will be agreed that his statement is correct. The telephone has not displaced the telegraph, nor has the radio displaced either of these. The railroad has not entirely superseded inland water-transportation, nor has the automobile superseded the railroad, and it is not likely to do so.

In the spring of 1923 a Transportation Meeting was added to the Society's list of meetings and that summer the American Electric Railway Association held its convention at Atlantic City and H. W. Alden, then President of the Society, was invited to address that meeting. The show that was held in conjunction with that convention had all the aspects of an automobile show.

Railroads Have Accepted Highway Transportation

Now we find that the railroads have accepted the fact that a field exists for highway transportation. At the December meeting of the Washington Section E. S. Pardoe gave these significant figures:

> At this time 6500 companies are operating 25,000 motorcoaches. Of these, 339 electric-railway companies operate 6500. In 1921 only 16 electric railways were operating 73 coaches. Now 31 steam railroads operate 350 motorcoaches.

I have heard the remark in connection with railroads and highway transportation that the simile of the lion lying down with the lamb might be carried further, and that they would rise together but with the lamb inside of the lion. Probably some justification exists for such a thought but I believe the recognition of the importance of highway transportation by the railroad systems is of itself a valuable contribution to transportation economics.

Competition between well-organized and responsible groups can be conducted if such competition is necessary, but this recognition by the railroads indicates that there is no such sharply defined competition as we ordinarily associate with the use of that term; rather, the automotive vehicle can be used as a valuable adjunct to the electric railway in mass transportation.

The same thing holds true in the transportation of goods. Unquestionably the industry has shown a tendency to build up a form of competition that has been unhealthy. The financing of sales of automotive equipment as it has been conducted probably has tended to the establishing of enterprises that were not founded on a sound economic basis. This is in the process of correction and I believe that these conditions will change.

Congestion Has Raised Difficult Problems

Finally, as we survey the field of the automobile, it seems to me we find that a definite interaction has occurred between the growth of the community and the use of the automobile. We are all familiar with the great growth of suburban and rural communities incidental to the growing use of the automobile and the development of good highways. This has brought about a condition of congestion which has raised problems that are extremely difficult to analyze. One of the phases of that analysis has been the thought we are giving to the small car. In addition to the necessity of studying the size of the vehicle and our means of communication as related to rearrangement of trunk roads, streets, bridges, and traffic tunnels, it will be necessary in connection with the planning of cities that consideration be given in the relatively near future to a decentralization of our activities. Instead of trying to arrange arteries of travel to bring the individual from the outlying districts to a central point for shopping or marketing, it may be necessary and desirable to transplant the shopping and marketing facilities to the districts in which people are now living as a result of the increased transportation facilities that are available. If these changes occur the increasing demand for transportation will continue, for they represent progress and increasing markets for the products in the building of which we are interested.

CIRCUITOUS GROWTH OF THE INDUSTRY

BY JESSE G. VINCENT[3]

ONE remarkable thing about the automotive industry is the ready way in which it absorbs its mistakes. I am reminded of the old blacksmith's complaint to his friend, a baker. "Joe," he said, "one nice thing about your job as compared with mine is that you can eat *your* mistakes."

As I look back over the years, I am impressed by the serene and steady progress of this industrial prodigy. We go merrily on our way, sometimes in a circle, but always forward. We may start with an L-head engine, then discover that an overhead-valve engine is much better, pass on next to a T-head, and finally come back and get all the thrill over again in discovering that the L-head engine is the best. Or perhaps we started building cars low and they stranded on a stone left thoughtlessly in the middle of the road, so we decide that more ground clearance is needed. Then someone builds an underslung model that looks like a dachshund and down come the other cars.

Twenty years ago tire troubles were real. Tires were delightfully uncertain; they might last 500 miles or might go 2000 miles. Then tires and roads were improved, the cord tire was perfected, and tire troubles were forgotten. Instead of a car wearing out 30 or 40 tires in a 24-hr. race, as used to happen, some tires even outlast the cars they are on. One would think that the pinnacle of success had been reached and that everybody should be happy. Nothing of the kind; the tire maker himself started us working all over again with balloon tires. Balloon is a good name; they certainly "put us up in the air" and some of us are not back to earth yet.

Other Reversions to the Primitive State

The history of automobile ignition is another example of what may be called reversion to the primitive state. Early automobiles were equipped with battery ignition, and more than once did milady have to leave her limousine in undignified haste because a short-circuit had caused the celluloid jars to flare up. No wonder magnetos were welcomed and preferred, for awhile. Then Mr. Kettering developed the self-starter and back we went to battery ignition.

Again, consider the dash and instrument-board. On very early cars the dash was unadorned except perhaps by the fabled whip-socket. Then engineers discovered this was a convenient place to patch on instruments and accessories, and a most impressive array of gages and gadgets, lubricators, manometers, thermometers, and tachometers followed. Later the engineers decided that these presented an unseemly exhibit to the public gaze and, figuratively speaking, the dash was swept clean

[3] M.S.A.E.—Vice-president, in charge of engineering, Packard Motor Car Co., Detroit.

over-night. But the scheming accessory engineer would not acknowledge defeat; realizing that the dash has two sides, he is now proceeding to cover the engine side with twice as many devices as ever adorned the visible side. As many as five different tanks of as many different shapes may now be attached to the dash if one can find room for them, and, as each of these magic tanks is reputed to lengthen the life of the car many times, it follows that we engineers will have plenty of time to improve our golf scores while the public is striving to wear out these ultra-durable cars.

Aeronautical Branch Held by Same Tentacles

This making of progress by advancing in circles has even fastened its tentacles on the youngest member of the automotive field, namely, the aeronautical branch. The Wright brothers started by giving us the biplane, a magnificent conception of the combination of maximum rigidity with minimum weight. Then followed the monoplane, largely sponsored by French designers and responsible for many casualties from structural failures. The biplane then returned to favor and a battle royal between monoplane and biplane at the Pulitzer Prize races in Detroit a few years ago resulted in definite victory for the biplane. The biplane enjoyed its supremacy for but a few years when the French won the world's speed-record with a monoplane and the Italians followed with their Schneider Cup racer. Similarly with aircraft engines, the Wright brothers used a water-cooled engine in the first airplane-flight. Then followed a long line of distinguished water-cooled engines, practically all of which in their original or modified form are still doing most of the world's flying and hold every world's record, whether for endurance, speed, distance or altitude. On the other hand, during the World War, rotary air-cooled engines were used to a large extent in the Allied pursuit-airplanes. Toward the end of the war the British evolved a radial air-cooled engine for which astounding claims were made, but its popularity was short-lived and water-cooled engines retained their supremacy. Now a wave of enthusiasm for air-cooled engines has developed and the pendulum is due for another swing.

What lessons are to be learned from these examples of engineering backing and filling? First, I believe they induce a spirit of tolerance. The successful automotive-engineer must be unbiased in viewing innovations. The fact that an idea has been tried in the past and found wanting should not be held against it. Secondly, we should adopt a policy of reasonable conservation and recognize our duty to furnish the public with reliable and economical transportation.

Lastly, we must cultivate a stout heart and be prepared to hear any day that some rival has rediscovered a principle we unearthed years ago and that the 1928 model of the famous Oshkosh will be equipped with hot-tube ignition, a balloon tire on the steering-wheel and with the rear axle in front.

NEED FOR IMAGINATION IN ENGINEERING

BY H. M. CRANE[3]

THE thought I have in mind is to present a call for the use of imagination, and always greater imagination, in our engineering work. I know that this is a somewhat dangerous term and would hesitate to use it with many company executives. Imagination, from their point of view, implies the making of frequent exaggerated claims of what a car will do or that it can be built for a specified price when that is not the case. The real definition of imagination, I think, is the ability to form a mental image of something that has never been seen.

One of the most notable, if not the most notable, examples of the use of imagination in this industry occurred some years ago when Henry Ford foresaw that the automobile would become a commonplace of daily life. The time will be remembered when the automobile was more or less of a sporting vehicle; when the business was currently called the "automobile game." We who are now marketing millions of cars a year are making tremendous profits in this business as a result of Mr. Ford's ability to break down the idea that a man who owns a motor-car is either a sport or a waster.

In my school days when I lived in a suburban town near New York City, the finger of scorn was pointed at a family that indulged in its first carriage. That act was talked of as "putting on a lot of front." The general idea was that if one commuted to the city he could walk to the station in the morning and to his home in the evening and on party days the family could hire a rig, unless the family was one of undoubted affluence.

On recent trips abroad it came very clearly to me that the condition which Mr. Ford exploded in this Country some years ago still exists in Great Britain and on the Continent. Unquestionably many families on the other side that could afford a motor-car of the types Mr. Fenn showed with his paper on English light-cars[4] feared to make the purchase because of the effect it would have on the opinion of their friends and the public. A slight symptom now indicates that this condition is being remedied by some of the makers but the conversion is going on very slowly.

Imagination Divides Engineer from Copyist

Imagination in engineering really divides the true engineer from the copyist. The copyist can look only backward or at the most sideways. The engineer with imagination is living in the future and preparing for what is to come, even though it is admitted that he cannot foretell exactly what that may be.

As an instance of the necessity of imagination in engineering, assume the fairly simple case of testing a new design of a passenger-car, a truck, or other motor-vehicle. It is necessary, in these days of speed in the industry, that tests be completed in the minimum of time. The successful man is the man who can bring to mind most completely the service that the car of new design must perform in parts of the Country which he never has visited and in the hands of persons he never has seen and does not know. If he does not do so, the tests are a failure; they mean nothing except a large waste of money and, what is more important, a waste of time. We all know of many tests that have been made and the reports of which have been filed carefully for future reference yet which have about as much bearing on the usefulness of the product tested as would the re-

[3] M.S.A.E.—Technical assistant to president, General Motors Corporation, New York City.

[4] See THE JOURNAL, February, 1927, p. 213.

lation between the height of a man and the distance he can jump.

If the testing of a completed vehicle is difficult without the use of imagination, how much more impossible is it for the engineer to conceive the design and complete the details of the design of a motor-car to fill a new field in the industry. Those of us who have dealt with motor-cars realize that nothing about them is capable of exact measurement. The motor-car is a highly developed compromise of conflicting desirable features. The specialist in engineering who sees only his pet hobby, whether it is a certain type of engine, some specific design of axle or spring-suspension, or something of that sort, can never in these days of great competition produce a commercially successful motor-car. We know that the public takes less and less interest in the mechanism that propels them along the road or how it does it. As a matter of fact, it never has taken an interest in the means of propulsion of any medium of transportation. All that the owner of a motor-car wants has been done when he has been provided with an engine that calls itself to his mind by giving him a violent push in the back when he presses on the accelerator.

The discussion of the light car at this morning's session of the Annual Meeting brought out again the need for imagination. No one in this Country who has simply played around in the ordinary course of life without using imagination can be expected to see why the motor-car developed along the lines it did on the other side. It is equally difficult for those who live abroad to realize why the motor-car is what it is today in the United States. While we cannot all visit Europe, we can do sufficient thinking, based on what evidence can be brought to us here, to understand some of the reasons for the differences. It would be a great mistake if the subject should be made controversial because this would prevent future development in this Country taking the lines it should take. If anything of value to us is embodied in the work of the engineers abroad, we should certainly take it, not when it is forced on us, but before it is even offered to us.

Must Meet Wants Before They Are Realized

Probably the greatest commercial opportunity in this age of rapid advancement comes to the man who fills a long existing want before the possible customer has become conscious of such want. This is exactly where imagination comes in. Many an unfilled want is unknown to the customer until the article appears before him; then it seems as if he had wanted it always. The need of imagination is most obvious in some of our forms of mass transportation of passengers and freight. The need of more engineering consideration for certain elements that undoubtedly affect greatly the cost of motor-car use has also been stressed. The organization with which I am associated feels that the greatest thing the industry can do is to make the use of automobiles as economical as possible, with the inevitable result that more of them will be used.

As an engineer I must admit that not enough attention is given to accessibility. It is most discouraging to visit the automobile shows and see how little attention is given to this detail, even in entirely new models that represent a complete new set-up of tools. The reason, I think, is that the public has made no coherent or clamorous demand for accessibility. If the demand exists it has not reached the ear of the sales organization, which is always one channel through which to secure action. But we cannot wait for a demand to make itself heard. The engineers in this industry owe it to their self-respect to make a much more definite attempt to make every part of the motor-car readily accessible so that the cost of operation can be reduced to the minimum and, more important, so that the useful hours on the road can be increased.

Imagination must include a constant searching of our methods. Too many ground-rules in our plants are based on tests made 10 or 15 years ago. In almost every case, when one of these ground-rules is examined, it is found that the reason for it has long since departed. This applies also to shops and machine-tools. The reason for some feature of design often is that certain tools that have been scrapped for 10 years were required for a certain method of machining. The reason for the design of a part to fit that particular system of tooling is long since gone; probably it costs more to do the work that way.

This is true of every part of the automobile; nothing is quite equal to going over the design thoroughly at least once a year and asking, What is this part for? and, Does this part that we are making do the work the best possible way and to the greatest advantage? We should produce the best automobile at the lowest price. Every ounce of metal in it, every screw or cotter-pin, must justify its place in the design by serving a useful purpose in the best way. If it does not, it must go out.

RESTRICTIONS ON THE ENGINEER

BY J. H. HUNT[5]

SINCE I have become more active in the more general phases of the automobile industry than when I was specializing in the electrical field, I have been trying to visualize just what we are about, where we are going and what we can do. The subject I have chosen to discuss is the artificial restrictions on the engineer, beneficial and otherwise. Some of these have not been discussed at our meetings as much as they might be with profit.

Mr. Crane referred to the artificial restrictions in production methods. I have known of developments by engineers that had to wait from 2 to 8 years until the management of the factory was willing to change the tool line-up so that a slightly different design could go through. This is a matter for which one might say the engineer is not directly responsible, but I think that, with competition developing as it is doing, it will be possible for the engineer to influence this situation, and where he can do so he should use his influence in such a way that the factory will not be hampered to the extent that it cannot avoid the circles in progress that Mr. Vincent spoke about.

Another subject is standards. These have not restricted development in the automotive industry. So long as the standards from which we can choose are confined to general applications and are as adequate as they have been up to now, we shall have plenty to choose from and will not be restricted to the use of anything that will not fit in with any reasonable program.

[5] M.S.A.E.—Chevrolet Motor Co., Detroit.

One of the fine things about automotive standardization is that the things we have standardized have not been very important individual problems; as soon as such problems become important, the function of standardization fades out. The standardization has been on the units that have enabled us to go ahead with the important things.

Influence of Legal Restrictions

A very clear exposition of what legal restrictions may do to an industry by restricting the ability of the engineer to produce the most desired result was presented at the Light-Car Session of the Annual Meeting. The British motor-car and, to a less extent, the Continental motor-car are what they are because of legal restrictions. An increasing disposition exists to interfere with the engineer in a legal way. I urge the engineer to use his influence as a citizen whenever possible to make clear wherever a proposed legal restriction comes up for discussion just how it will handicap development. If we do what we can in this way, without showing too controversial a spirit, something can be accomplished.

Labor regulations are another type of artificial restriction that can become very harmful. Mr. Fenn pointed out at the session mentioned that certain designs or materials had been found desirable and had profited simply because labor restrictions in certain lines of work prevented development in the normal way. Many examples of this have come to our attention in connection with the British automotive industry. In this Country efforts have been made recently in certain States to enact laws, frequently at the instance of labor organizations, that would restrict the use of certain tools or processes in the factory instead of being directed toward the elimination of any evils that might exist in the specific process at the time. For example, in the matter of lacquer finishes, instead of requiring that the necessary ventilation be provided, effort has been made to prevent the use of the material. Fortunately the American public has not permitted much legislation of this kind so far and I think it is the duty of the engineer, wherever possible, to use his influence to try to maintain this same situation.

Regulation and inspection by legal and other bodies working in somewhat the same way bring up an important subject. In my opinion we deserve most of the restrictions of this sort that have been imposed and we can only do everything possible to secure the removal of those we have inherited and try not to deserve others in the future.

Danger from Imposed Guesses at Results

I hope that what I say in regard to insurance and inspection service will not be misunderstood. In the early days of the automobile we were entirely too careless about the fire risk; this was especially true when the electrical equipment was extended from the ignition system to a large number of the accessory functions on the car. As a result we had an unreasonable number of fires. The Underwriters' Laboratories performed a great service in connection with improving that situation. In their first work they were very constructive in bringing to attention the fact that certain structures had been proved in service to be very successful and that other structures had been unsuccessful. They also adopted a system of encouragement through reduced insurance rates on the satisfactory structures.

Sometimes a disposition has been shown by some to try to carry this work beyond the point of basing the suggested improvement on experience and attempting to predict what will happen with an untried design and an attempt to influence design. I believe that the tendency, however well meant, is unfortunate. I want to make every effort to cooperate with the underwriters and any one else who wishes to improve our product, but I wish to point out and emphasize as strongly as possible that the only basis for success along this line is field experience, that the guess of an engineer in one laboratory is not necessarily better than that of an engineer in some other laboratory, and that everyone should be slow either to push or to place restrictions on a design based on what might happen rather than on what actually has happened.

The headlighting question has brought us into contact with regulating authorities and with the results of their work. I do not criticize the regulating authorities for wanting to do something; the situation was bad, but a great deal of soothsaying has been manifest in connection with the regulation of headlighting. We are told that a large percentage of accidents is due to headlights, but I am relieved to note that official figures show that the majority of accidents happen between 4 and 6 o'clock. It is obvious that the headlights cannot have a great effect, in the course of the whole year, on the accidents that occur in this period, yet a situation has developed recently that has been very trying to anyone who wished to contribute in any way to the improvement of the headlighting situation.

Authority Exercised in Wrong Directions

Our regulating authorities have been given the right under the laws to predict a little about what is going to happen. They do not pass upon the result of the lighting but are authorized to approve or disapprove lighting systems or devices if, in the opinion of the regulating authority, proper results will or will not be obtained with them. This led to a situation which made it look as though it would be impossible, if the people involved in the argument continued to maintain their position, to ship automobiles with headlights on them. It would be necessary to set up warehouses stocked with lamps and install the head-lamps after the cars arrive in the State, because one group of authorities took the position that unless the lamp was made in a certain way good results would not be obtained and another group of authorities insisted that they would not permit that same type of lamp to be used.

The whole difficulty arose because men who wish to accomplish a given result were trying to specify, not the result, which in many cases they have a right to specify, but the means to that result. When they all get through specifying the means, they will have done our engineering for us and there will be nothing for us to do.

This industry developed because it started in a country where we were not tied down with legal restrictions and with ideas as to the amount of money a family should save. If we had the theory that a man should save enough to retire at 50 years of age and provide for a relatively expensive education for his family, as was the theory of the middle-class people in France before the war, it would have been impossible for Mr. Ford or anyone else to apply momentum in the automobile industry. The industry grew rapidly because we were free to use such brains as we had and, by successively trying-out various ideas, secure a result that seemed to possess some value. What influence we have should be applied to an endeavor to maintain this situation insofar as possible.

FUEL STATUS AND ENGINE DEVELOPMENT

BY C. F. KETTERING[6]

THE subject I am going to talk about was brought to mind by a meeting this forenoon with the Technical Committee of the Oil Conservation Board who came to Detroit, not knowing that the Society was in session, to visit the laboratories of our company. The Oil Conservation Board was appointed by the President a little more than 2 years ago to investigate oil production and consumption. At present we do not produce much more petroleum than we are using. The question that has been asked in a questionnaire sent to a great many persons in the automotive industry is, What is the future position of the fuel supply to the automotive industry?

Half of the Country's horsepower today is represented by automobile engines. Allowing 20 hp. as the average actual power of automotive engines in 20,000,000 vehicles gives 400,000,000 hp., which is more than half of the developed horsepower for all industries. The consumption of fuel, which was 10,000,000,000 gal. last year, will perhaps go to more than 11,000,000,000 gal. this year. Therefore, whatever can be done to get more work out of our fuel or to find other sources of supply is an important matter that is being given consideration by the United States Government, not so much to offer a solution as to present a set of consistent data.

It does not seem at present that vehicle users are interested so much in economy as in performance; but much that is done to improve economy will improve performance also. We are on the eve of the introduction of the high-compression engine. We are starting in on a long line of development. No one knows how long it will take to develop an improved engine of from 25 to 35 or 40 per cent increased fuel-economy.

Recently we listened to a paper on the conversion of coal[7] into liquid fuel by hydrogenation. These processes are of great importance in countries that have only a small quantity of crude oil. All of the new factors that can enter to increase fuel-efficiency are of importance to us also, not so much today as they will be in the future.

I think the work that the Oil Conservation Board is doing is of great importance toward giving us an exact knowledge of what this situation is and of what it will be, particularly on account of the tremendous increase in automotive vehicles, the introduction of large internal-combustion engines for other uses and the probable use of Diesel engines in rail-cars. A race open only to cars driven by oil engines is planned to be held in Indianapolis and will excite a certain amount of interest in the lower-grade fuels.

[6] M.S.A.E.—General director, research section, General Motors Corporation Research Laboratories, Detroit.

[7] See THE JOURNAL, January, 1927, p. 98.

NICARAGUA

INCREASING traffic through the Panama Canal indicates that the construction of a second canal will eventually become necessary. Following the ratification in 1916 of a treaty involving a payment of $3,000,000, Nicaragua granted to the United States the exclusive right to construct and operate such an ocean-to-ocean canal across its territory.

Nicaragua is the largest of the Central American countries. With an area of 49,000 sq. miles it is almost exactly the same size as the State of New York. The most striking topographical feature of the country is the immense inland body of water of the same name as the country. It is by far the largest lake between Lake Michigan and Lake Maracaibo. The travel facilities furnished by its 100 miles of length and 40 miles of breadth combined with those of its outlet, the San Juan River, have played a major part in the history and development of the country. Up this river and across Lake Nicaragua runs the route of the proposed canal, with but a few miles of land separating the lake from the Pacific. Lake Managua, together with the river connecting it with Lake Nicaragua, extends the possibilities of navigation in a north-and-south direction by a distance of approximately 50 miles.

Although Lake Nicaragua at its closest point is only about 13 miles from the Pacific Ocean it drains southeastward to the Caribbean Sea, a distance of about 120 miles. Throughout its course the San Juan River averages about 1000 ft. in width. A sand bar across its mouth and four rapids make navigation hazardous. The drop from the lake to the sea is 110 ft. The lowest point in the divide between the lake and the Pacific Ocean is only 135 ft. above the level of the lake. The mountain range west of the lake and extending northward is of volcanic origin and varies in altitude from about 135 ft. at the southern end to some 6000 ft. toward the northern.

The population is predominantly Indian, much mixed with Spanish blood. About three-fourths of the total of between 600,000 and 700,000 live in the comparatively small area west and north of the lakes. Agriculture is by far the leading industry. In 1925 coffee, bananas and sugar made up 72 per cent of the total value of all exports. Though potentially a highway of world trade, lack of roads and railroads at present constitutes a formidable barrier to Nicaragua's commercial and industrial development, five railroads operating over a total trackage of 203 miles. To supplement its limited rail facilities only 150 miles of motor roads and some 200 miles of cart roads are available. The populated region about the lakes is almost entirely cut off from the east coast and shipments from one coast to the other frequently go 1500 miles by way of the Panama Canal. For 30 years the agitation for an ocean-to-ocean railroad to remedy this situation has been going on, but the line is yet to be built.—*Commerce Monthly.*

BASIC FACTORS IN BUSINESS

AFTER a review of the principal factors that have contributed to the remarkable business development of the last 4 years, giving due weight to each, the one greatest factor that has constituted the rock-bottom basis of this new buying appears to have been the increased productive efficiency of management and labor plus the distribution of the increased product largely to the consuming public in the form of wages. To argue as to which of the latter two, the increased productivity or the higher wages, was the cause of the other is useless. No doubt stubborn resistance to wage reduction constituted a tremendous pressure which forced efficiency in industry, but to continue to pay such abnormally high wages without the increased efficiency would have been impossible. The basis for our ability to continue to maintain these wages, therefore, is unquestionably the increased efficiency of our production units. The essential conditions to the maintenance of a large volume of business in a reasonably self-contained economic unit such as the United States are:

(1) A high degree of productive efficiency
(2) A wide distribution of income and a high standard of living
(3) A proper balance between consumption and saving and in capital equipment as among the various industries
(4) Ample credit facilities well controlled
(5) Confidence in the future

The existence of a wide distribution of income and of a high standard of living is no longer a matter of doubt in this Country. Never before have the present standards among the industrial classes been equaled. We have the productive efficiency with which to produce the values that make possible the payment of the high wages, which in turn provide us with a large domestic market. Our records of individual savings, plus accrual of corporate surpluses, present clear evidence that the higher standard of living has not resulted in a reduction in our capital savings. We have ample credit facilities, for the most part well controlled. In other words, with unimportant exceptions, we have about every economic factor necessary to the continuous and reasonably profitable operation of the larger part of our productive plant.

The notable advance in the study of underlying factors in business that has taken place in the last half-dozen years has done much to free American business from the influence of so-called psychological forces. The wider knowledge of economic conditions and former grasp of fundamental facts leave the business man less in the dark than formerly. We have, therefore, in this increased knowledge, if not a preventive of temporary loss of balance, at least a force operating to reestablish psychological equilibrium. In the future, therefore, we may well expect recessions to be of less depth and of shorter duration than in former years.

However, a tendency still remains to think of the future of business too much in terms of so-called key industries and to formulate business judgment by reference to temporary tendencies in these industries. If a sufficient number of people believe that the automobile or any other industry is the key to present prosperity, then a recession of that industry will of itself cause a recession in general business. We know that fear or apprehension exercises upon business activities influences somewhat similar to those that they exert upon the physiological; they bring about something akin to temporary paralysis of certain nerve centers, and assimilation is retarded. But once this apprehension is removed—given, of course, a body organically sound—normal functioning is resumed.

The American economic body is organically sound. The volume of new business in some of the so-called key industries may decline and a psychological reaction resulting in a decline in the general volume of business may follow, but unless some economic maladjustment more serious than anything now in sight should develop the recession, if it comes, should be short-lived and business should soon regain its forward advance.—H. A. E. Chandler in *Commerce Monthly*.

CLASSIFICATION OF AIRCRAFT

FEW developments in transport by air have been of more significance than the arrangement that has been made by a group of classification societies for dealing with aircraft in exactly the same way as they now deal with sea-going vessels. The Bureau Veritas, the British Corporation Registry, the Germanischer Lloyd, the Norske Veritas, the American Bureau of Shipping, and the Imperial Japanese Maritime Corporation have decided to cooperate in drawing up international rules for the construction and maintenance of ships of the air, compiling and keeping uptodate an international register of aircraft, surveying and classifying all such craft, and granting certificates of fitness that will be accepted by underwriters. In other words, these very influential bodies have officially recognized transport by air as of equal importance, from their point of view, as transport by sea; and their arrangements go even farther than those under which they deal with sea-going vessels. The rules will be common to all the societies, and the survey and certificate of one society will be recognized fully by all the others; so that, for all practical purposes, there will be only one society.

Two notable absentees from the list of societies may be noticed, Lloyd's Register and the Register Italiano. The latter is already closely associated with the British Corporation Registry, and will, no doubt, come into line in due course. It is hardly a free agent as are the others, seeing that it has certain State connections. As for Lloyd's Register, its vast organization is bound to be utilized eventually for the supervision of aircraft construction and maintenance, and that its committee has the matter before it goes without saying. Progress in putting air transport on a regular trading basis has been slow, so far, but nothing will give the public greater confidence than the official recognition of the classification societies; and nothing will do more to ensure not only that aircraft are of sound construction but that every possible advantage is being taken of whatever is available in the way of scientific progress.—*Modern Transport.*

ACTIVITIES OF THE SECTIONS

(*Continued from p. 442*)

the thin wall of the cups and is preheated to a temperature that is safely below the point of vaporization. It is then forced out by the succeeding fuel charge into a conical plunger chamber, where it stands in a little pool directly over the spray-nozzles. On the compression stroke the heat of compression is driven up through this pool and the fuel is further preheated and thoroughly prepared for injection. At approximately top center of the piston stroke the charge of vaporized fuel is injected into the heated compressed air just fast enough to burn without an appreciable rise in pressure. Every vital functioning part is positively operated mechanically. The volume of the preheating chamber is made very small to avoid the presence of too much oxygen, which would cause combustion in the chamber, but the incoming compressed air is forced through the fuel at its highest temperature. As the charge is in the form of a more or less dry gas when injected into the cylinder, combustion occurs the instant the charge comes into contact with the air charge in the cylinder and combustion is completed early in the stroke, which results in high mean effective pressures, good fuel economy and low exhaust-temperatures.

R. R. Teetor

C. L. Cummins

P. M. Heldt

W. G. Wall

FOUR MEMBERS OF THE SPEAKER'S SEXTET AT THE OIL-ENGINE MEETING OF THE INDIANA SECTION

Mr. Teetor, Chairman of the Section, Presided; Mr. Cummins Presented a Paper Describing a Special Ignition-System for Oil Engines; Mr. Heldt, in an Interesting and Informing Paper, Reviewed the Development of the High-Speed Diesel-Engine Both Here and Abroad; and the Whole Subject Was Summed Up by Mr. Wall, Who Compared Oil and Gasoline Engines and Listed Their Advantages and Disadvantages

STATUS OF HIGH-SPEED DIESEL ENGINE

The lighter-weight high-speed Diesel-type engine is rapidly becoming a reality, declared W. W. Schettler, chief engineer of the Foos Gas Engine Co., who said that the progress made in the last year or two in experimental laboratories indicates that these higher speeds are not impossible nor improbable and that reliable commercial-type Diesel engines can now be obtained in sizes from 50 to 400 b.hp. that will operate continuously at from 200 to 900 r.p.m.

The requirements for a successful high-speed engine were listed as: (*a*) careful balancing of moving parts, (*b*) ample factors of safety, (*c*) light weight, (*d*) reliability and consistently trouble-free performance under adverse conditions, (*e*) small physical proportions relative to power developed, (*f*) complete enclosure of working parts, (*g*) adequate lubrication by an automatic system and elimination of oil-holes and grease-cups, (*h*) general simplicity of design, (*i*) ruggedness of working parts consistent with light weight, and (*j*) accessibility for inspecting and adjusting the engine quickly while it is in service.

Builders of high-speed Diesel engines have departed from the somewhat conventional practice in a number of instances, said Mr. Schettler, and to a limited extent have adopted automotive design and modifications. A dozen lantern slides of Foos engines and details of their design were shown. These engines were designed neither for extremes in speed nor light weight but as light-weight heavy-duty engines for the exacting service required of cranes, drag-line excavators, shovels, marine applications, rail-cars and locomotives and also for stationary duty. The Type-L engine is a full Diesel four-stroke-cycle engine with mechanical solid-fuel injection and has a speed range up to 900 r.p.m., at which it develops 60 b.hp. per cylinder. The weight is 40 lb. per hp. with cast-iron base and 30 lb. per hp. with aluminum and steel castings.

HIGH-SPEED DIESEL-ENGINE HISTORY REVIEWED

The history of the development of the high-speed Diesel-type engine in Europe and in this Country was reviewed interestingly and instructively by P. M. Heldt, technical editor of *Automotive Industries*, who illustrated his paper with many slides. He began by defining the Diesel four-stroke engine as the same as the conventional automobile engine except that (*a*) instead of drawing in a combustible charge of air and gasoline vapor, it draws in air only; (*b*) during the compression stroke it compresses this to 1/12 or 1/15 the original volume; (*c*) at the end of this stroke the fuel is injected by high pressure; and (*d*) the high heat of compression of the air ignites the charge spontaneously, hence no ignition apparatus is required. Although no carburetion and no ignition means are required, a fuel pump and an injector valve for each cylinder are needed.

One of the engineering developments of the next decade undoubtedly will be a wide application of oil-burning engines to land transportation, asserted Mr. Heldt. Experimental Diesel engines have been built in virtually all sizes, down to one for a motorcycle, but for automotive work it usually is necessary to reduce the weight per horsepower materially, which necessitates operation at relatively high speed and introduces additional difficulties. In England, he said, the development of the oil engine for aircraft work has been taken up in a systematic way and a committee of the Air Ministry pointed out in a long report that any reduction in the weight of fuel needed for a long flight may be set off against any increased weight of the engine and that the longer the journey the more the fuel economy will compensate for a heavier engine. In this connection the speaker mentioned an English compression-ignition engine that is reported to have developed 1 hp-hr. on a fuel consumption of 0.365 lb. of fuel, which is much better than any results obtained with a carbureter-type engine.

Details first published in 1926 of the Maschinenfabrik

Augsburg-Nurnberg Diesel engine built in Germany for truck use show it to be a four-cylinder engine of about 4½ x 5⅞-in. cylinder dimensions and to have a weight of 22 lb. per hp. at 1000 r.p.m., with a fuel consumption of 0.44 lb. per hp-hr. under full load at 800 r.p.m. The Maybach crude-oil engine designed for rail-cars and marine use is a six-cylinder engine and develops from 120 to 130 hp. at 1300 r.p.m. It is one of the few automotive-type Diesel engines that use air injection for the fuel.

Developments in this Country by the American Bosch Magneto Corporation and Elmer A. Sperry and in Canada by A. C. Attendu, of the Eastern Engineering Co., along the line of oil-engines for aircraft work were reviewed, together with mention of work by various companies in the field of oil-engines for industrial and automotive purposes.

Small likelihood exists of this general type of engine coming into use in passenger-cars, at least for a considerable time, in Mr. Heldt's opinion, as its chief advantage is reduced fuel cost, and fuel now represents only about 15 per cent of the total cost of operating and maintaining a motor-car. But for rail-cars, which may burn as much as $50 worth of gasoline per day, it may convert an unprofitable service into a profitable one, and from the rail-car the engine will make its way downward into the field of smaller vehicles.

The whole subject was summed up in conclusion by W. G. Wall, who gave a list of the advantages and disadvantages of the oil-engine as compared with the gasoline engine.

SIX-CYLINDER ENGINES FOR TRUCKS

Advantages Told by Favary at Southern California Section Meeting

E. Favary

Increased mileage per gallon of fuel, more rapid acceleration, greater speed, and almost total absence of vibration are some of the more notable advantages of the six-cylinder-engined truck over one equipped with a four-cylinder engine, declared Ethelbert Flavary, of the Moreland Motor Truck Co., at the monthly meeting of the Southern California Section at the City Club, Los Angeles, on March 11. His was the only technical address of the evening, but the gathering, over which Eugene Power, chairman of the Section, presided, listened first to a talk by Judge Richardson, magistrate of the City Court, who spoke of traffic congestion, minor violations of traffic regulations that cause most of the accidents and lack of street-name signs in the City.

Judge Richardson urged the automotive interests to use their influence with the City Council or the Board of Public Works to have large street-signs placed on both sides of the streets and so placed or of such a character that they can be read easily at night. He referred to a company that is trying to secure adoption of luminous signs that will glow for 6 hr. after a period of 2 hr. of sunlight. Imagine what a great improvement it would be and what a large amount of damage would be avoided if cars were fitted with luminous signals so that the car ahead would be visible at night whether the tail light was burning or not, said Judge Richardson. Traffic cases are now being handled by Judge McConnell, he said, who is attempting to solve the traffic problem of Los Angeles, which is becoming more difficult every day because the number of vehicles is increasing while the width of the streets is not. It is for the automobile men to help by observing the law and in the great work of saving life, concluded the speaker.

Why Six-Cylinder Engines Are Superior

Advantages of the six-cylinder engine for passenger-cars have long been recognized, but only comparatively recently have its merits for freight and mass-passenger transportation been appreciated, Mr. Favary reminded his hearers in introducing his subject. Well-known advantages of the six-cylinder engines were referred to as (*a*) 50 per cent more power strokes per revolution of the crankshaft than in the four-cylinder engine; (*b*) overlapping of the power strokes, which gives more constant driving-torque and decreases intensity of vibrations; (*c*) greater power obtainable, with corresponding decrease in weight of reciprocating parts; (*d*) quicker acceleration, due to the foregoing; (*e*) ability to run at high speed without laboring.

Contrary to former belief, it has been shown that the six-cylinder engine has greater thermal efficiency than the four-cylinder engine, asserted Mr. Favary. Despite the possible greater loss of heat through the cylinder-walls due to the larger ratio of wall area to cylinder volume, the engine is capable of transforming a larger number of heat units into useful work, because of reduced vibration and, perhaps most important, it is possible to use higher compression-pressure without detonation. Not sufficient importance has been placed on this possibility. Heat is conducted away from the top centers of small pistons to the cylinder-walls more readily than from larger pistons, hence the centers are cooler; moreover, in the smaller combustion-chambers the distance from the spark-plugs to the farthest layers of the combustible mixture may be less, and therefore the likelihood of part of the unburned charge becoming heated to the point of detonation by the burning charge is decreased. Consequently, a small-bore engine makes possible the use of higher-cylinder-wall temperatures and higher compression-pressures.

Mr. Favary then proceeded to show by formulas and charts that in high-speed engines the maximum strain on the crankshaft occurs at the end of the exhaust stroke and that the piston moves faster during the upper half of its stroke than the lower half because of the angularity of travel of the connecting-rod. The inertia forces of the reciprocating parts introduce high bearing-loads. Cranking in bearing-pressures with minimum pistons and connecting-rods of half of the weight of cast-iron pistons and forged-steel rods are only half as great as with the latter, he showed. On the other hand, wristpin pressures per square inch of pin area are increased by about 20 per cent with aluminum pistons. Stresses in aluminum connecting-rods also are considerably higher than those in steel rods, Mr. Favary asserted, and allowance should be made for this when designing duralumin rods.

Vehicle Performances Compared

Departing from the theoretical and mathematical, the speaker told of actual comparative results obtained with a four-cylinder and a six-cylinder engine installed in a truck of 1 to 2 tons' capacity. The two engines compare as follows:

Number of Cylinders	4	6
Piston Displacement, cu. in.	251.3	230.2
Weight of Steel Connecting-Rod, lb.	3.375	2.375
Weight of Piston with Pin and Rings, lb.	4.000	2.062

While the four-cylinder engine develops its maximum of 46 hp. at 2000 r.p.m., it could not be run at this speed because of excessive vibration. The six-cylinder engine develops its maximum of 56 hp. at 2600 r.p.m., and at this speed the absence of vibration is very noticeable, said Mr. Favary. The torque curve of the latter engine varies only slightly for speeds between 400 and 2600 r.p.m., but that of the four-cylinder engine drops rapidly above 1200 r.p.m. With the six-cylinder engine, the truck showed greatly improved acceleration, higher speed, more constant torque at all speeds and from 12 to 13 miles per gal. of fuel as against

10 miles per gal, with the four-cylinder engine, or a gain of 25 per cent in fuel economy.

It is confidently expected, said Mr. Favary in conclusion, that engine builders will increase the compression pressures in the smaller-bore engines and thereby increase their efficiency and fuel economy.

Discussion Covers Various Points

Drivers almost fight for the privilege of driving the 12 or 15 six-cylinder-engine six-wheel trucks operated by the company with which he is connected, said W. B. Agler, of the Associated Oil Co. These are oil-tank trucks of 1600-gal. capacity, equipped with air-brakes and have extra deep seat-cushions. They are operated between Los Angeles and Bakersfield and require less maintenance work than the trucks equipped with four-cylinder engines, due principally to freedom from vibration. They travel at a speed of 35 m.p.h. when light and as fast as the drivers want to run them when loaded. E. R. Nash, of the Cousins Tractor Co., reported that he found no comparison between the performance of two trucks before and after six-cylinder engines had been substituted for four-cylinder units by the company; and Mr. Adams, of the Southern California Telephone Co., stated that this company is experimenting with light six-cylinder trucks and is well pleased with them.

The cost of a truck equipped with a six-cylinder engine is about 25 per cent less than one having a four-cylinder engine, Mr. Favary said in answer to a question. This is due to manufacturing methods and the production of six-cylinder engines in larger numbers, it was explained. Replying to another question, he explained that although the maximum pressures on the connecting-rod bearings are greater with aluminum pistons and duralumin rods, the average pressures are less. Satisfactory lubrication is more difficult with aluminum than with cast-iron pistons, but if properly designed both give good results.

If speeds were increased considerably the pressure due to gas would not increase to any great extent, remarked C. H. Paxton, of the University of California, but the inertia and reciprocating forces would increase appreciably, hence each engine should be designed in accordance with the average speed at which it is to run.

Replying to an inquiry by C. B. Elliott, of the California Institute of Technology, if he thinks the eight-cylinder engine will replace the six-cylinder type eventually in trucks, Mr. Favary said that he did not see much likelihood of this unless the size of the powerplant, total weight of the truck and the speed are greatly increased, but speed is limited by law.

He was not prepared to state, he said in reply to a query by Mr. Nash, how much the compression-ratio can be increased because of the great heat-conductivity of aluminum pistons, but he had found, in earlier days, that to cause aluminum pistons to remain cooler it was necessary to increase the thickness of the piston-head, and this increased the weight almost to that of the cast-iron piston.

The suggestion was made by Mr. Dixon, representing Zenith carbureters, that increased engine efficiency might be obtained by the use of a thermostat to maintain a higher jacket-water temperature and to avoid rapid cooling during short stops or when coasting down long hills.

Offensive Fumes Discharged

Considerable discussion regarding the discharge into vehicles of offensive gases by six-cylinder engines brought the meeting to a close. Mr. Patton, of the Motor Bus Co., remarked that when the engine is shut-off a rush of gas through the exhaust-pipe occurs and this is drawn in under the vehicle. Mr. Dixon stated that this occurs just at the end of deceleration, which led to the belief that while the engine is slowing down the heavier ends of the fuel are carried into the cylinders in such quantity that they are not fully burned but pass out in the form of a hot vapor. R. H. McNeish, of the Los Angeles Fire Department, added that when running on schedule time and carrying a load, it is necessary for the driver of a motorcoach to keep the throttle open almost until he is ready to stop. More of the heavy ends of the fuel will then lie in the intake manifold and when the throttle is closed and the clutch disengaged the harder suction will draw this heavy fuel into the cylinders. Then it will be discharged, unburned, through the exhaust-pipe as foul smelling fumes.

Six-cylinder engines fitted with double carbureters show better acceleration, better power, and between 11 and 12 per cent greater mileage per gallon of gasoline than when a single carbureter is used, declared Mr. Dixon. The difference in acceleration is very noticeable. The only way in which he can account for the improvement in performance is that the mixture is distributed better to all of the cylinders. Mr. Patton stated that the cause of the trouble is now being sought for in the manifold and that his company has motorcoaches on which two new special manifolds are being tried. Three out of five men who drive the same vehicle say that it "gasses" and two say that it does not. Only one motorcoach "gasses" badly and, as the carbureters are of the same kind, he is inclined to think the engine is the cause.

SPECIAL AUTOMOTIVE MATERIALS

Detroit Section Told How Rubberized Fabric and Artificial Leather Are Made

Two papers were presented at the meeting of the Detroit Section that was held on March 24 in the General Motors Building. They told the story of the manufacture of artificial leather and of rubberized fabrics, and explanations of the testing of these products were made, together with exhibits of samples of the materials entering into their composition and illustrations of the various processes.

The paper on Rubber-Coated Automotive Fabrics was presented by M. N. Nickowitz, technical superintendent of the Fairfield, Conn., plant of E. I. Dupont de Nemours & Co., Wilmington, Del. He outlined the history of rubber, cited the substances that enter into the composition of rubber-covered fabric and quoted statistics to indicate what enormous quantities of such material the automotive industry consumes. He then enumerated the physical tests to which the compounds and substances are subjected before being used, and the tests made on the finished product.

Manufacture, Testing and the Use of Leather Substitutes was the title of the paper presented by E. H. Nollau, chemical superintendent of the Dupont Company. He said in part that the idea of a substitute for leather dates from about 1855. The industry was started in England and was introduced into the United States between 1890 and 1895. In 1921 approximately 9,888,000 sq. yd. of leather substitutes was consumed and in 1923 about 18,480,000 sq. yd., an increase of about 87 per cent in 2 years. New uses for the product have continuously arisen. Great expense has been in-

M. N. Nickowitz

E. H. Nollau

Speakers at the March 24 Meeting of the Detroit Section
The Steps in the Manufacture of Artificial Leather and Rubberized Fabrics and the Tests to Which the Finished Products Are Subjected Were Described

curred in improving the manufacturing processes, in developing new types and in improving quality and durability. In addition to its use for upholstery, leather substitutes are used for such purposes as spring boots, tops, radiator covers, tire covers and the like. The varieties are from light-coated sheetings to heavily coated sateens, ducks, drills and moleskins. Mr. Nollau remarked that artificial leather is not necessarily a cheap substitute for leather. Actual tests have shown that, in many instances, it is preferable to other materials, even disregarding cost advantages. He gave a detailed description of the manufacture of leather substitutes and of the tests made on the constituents and on the completed product.

In conclusion Mr. Nollau said that there is an obvious need for standardizing a commodity having such extensive uses as artificial leather. The automobile builder can hardly be expected to be conversant with all the details of the manufacture of the material as well as its general physical properties. By not having this information in some form or at least available, the consumer might often pay more than is necessary for the type of material he needs for a particular purpose. A matter of importance to the consumer is that of total weight of the material per yard—whatever the width may be—weight of coating material and weight, count and construction of the fabric. These data can be secured by a comparatively simple analysis that the consumer himself can make if he desires. The other tests described can be made by the manufacturer in the regular control work on his product.

GASOLINE-DRIVEN RAIL-CARS

Internal-Combustion Engines in Rail Service Entertains Pennsylvania Section

A. H. Candee

The use of internal-combustion engines for propelling railroad cars is merely the application of basic economic principles to practice. Adaptation of efficient machines or tools to save human labor has been responsible in large measure for present-day civilization and prosperity. When we speak of machines and tools, we naturally think of factories and machine-shops; but railroads are also manufacturers. Their product is ton-miles and passenger-miles. The measure of the effectiveness of the railroads as manufacturers is the selling price of their product as against the cost of production. They should therefore be interested in any tool that will increase the differential between the price received and the cost of production. Thus A. H. Candee, railway engineer, Westinghouse Electric & Mfg. Co., introduced his talk on the Use of Internal-Combustion Engines in Rail Transportation at the monthly meeting of the Pennsylvania Section at Philadelphia on March 8.

Had the steam locomotive been less reliable and less versatile than it is, said Mr. Candee, the growth of the Nation would have been stunted. Steam locomotives are the result of 100 years of development, consequently any new form of motive power enters the field under a severe handicap and must be thoroughly tried and proved before it will be given serious consideration. It has already lost the race for supremacy in certain classes of service, such as that of suburban and terminal service; but in many places it cannot be replaced.

Mr. Candee then reviewed some of the early attempts to operate rail-cars propelled by internal-combustion engines, stating that their development had slowed down and finally stopped from 1914 to 1920. Beginning again about 1920, small cars similar to highway trucks with flanged wheels had been constructed. Progress since that time had been rapid until at present between 450 and 500 gasoline-driven rail-cars are in operation in this Country. Recent signs also include the use of Diesel engines and oil-burning locomotives. The locomotive field, said Mr. Candee, holds greater promise than the rail-car field, because the demand is for the replacement of 75,000 steam locomotives, whereas the demand for rail-cars is for only from 3500 to 5000.

In considering the economics of the situation, Mr. Candee said, reliable operating results have been obtained only on rail-cars. Steam-train costs on branch lines vary from \$0.75 to \$1.50 per train-mile, with an average of from \$0.90 to \$1.00, but the service can be handled by gasoline-driven engines at a train-mile cost varying from \$0.30 to \$0.60, with an average approximating from \$0.36 to \$0.40, including fixed charges. Oil-engine-driven trains operate at a cost of between \$0.25 to \$0.50 per train-mile, with an average of from \$0.33 to \$0.35, including fixed charges. In addition, a number of indirect returns are exceedingly difficult to evaluate, such as reduced maintenance of right of way, reduction of attendant facilities and charges and improved public relations.

In thermal efficiency, continued Mr. Candee, the steam locomotive is admittedly low, being not more than 6 per cent at the rail, whereas that of the gasoline-driven powerplant is as high as 20 per cent. The average steam-locomotive operates about 113 miles per day, the distance from Pittsburgh to Altoona, Pa., over the Pennsylvania Railroad. An internal-combustion engine powerplant can easily average three or four times this distance.

For stationary and marine purposes, the weight of oil engines ranges from 60 lb. per hp. upward, whereas when used in rail vehicles, they must weigh less than 45 lb. per hp., and preferably not more than 20.

Mr. Candee mentioned several types of transmission that had been tried and remarked that the Boston & Maine Railroad had recently placed an order for a 1600-hp. Lomonosoff locomotive built in Russia that utilizes a magnetic clutch with the gears constantly in mesh. Electrical transmission, said Mr. Candee, enabled the utmost use to be made of the engine and curves show that a 1250-hp. locomotive with electrical transmission has better performance throughout than a 1600-hp. locomotive with mechanical transmission, even though the losses in mechanical transmission are claimed to be lower than those of the electric drive.

In conclusion, Mr. Candee asserted that although the position of the steam locomotive is not threatened in the near future, its future position will depend upon the rate of progress provided by designers. It will be supplanted in many places by electrification, because of the greater economy of electric operation, and internal-cumbustion engines will probably supersede it on light-traffic lines, in switching service and where fuel and water are hard to obtain.

In a written discussion, W. C. Sanders, general manager of the railway division, Timken Roller Bearing Co., explained the advantages to be derived from the use of roller-bearings in reducing a starting resistance. Comprehensive tests, he said, have shown that the saving of power by their use is approximately 10 per cent.

FUEL WASTAGE

DESIGNERS will undoubtedly be forced before long to deal seriously and properly with the carburetion problem. As the matter stands today, it is only half-completed and remains at the same stage fundamentally as it was 20 years ago. This is the more discreditable when the fact is borne in mind that we have a vastly increased knowledge of fuels and their characteristics upon which to draw. We also, of course, have a much wider experience in the design and functioning of carburetion systems than was the case a decade or two back. Today, therefore, little reason why the problem should not be dealt with satisfactorily seems to exist.

The whole subject of fuel wastage is, of course, one of national and international importance. Enormous quantities of gasoline might be saved yearly if it were only used with some degree of efficiency. The state of the air in the streets of towns today is simple testimony to the faultiness of combustion processes in the motor-car today. The fact that the average car needs decarbonization every 3000 or 4000 miles, often sooner, is a lamentable confession of failure. The gross world-wastage must reach an appalling figure. A sense of smell alone provides all the evidence necessary regarding the present state of affairs. As soon as most engines depart from some ideal speed or throttle opening, nauseating richness occurs.

The problem splits up naturally into two parts: the provision of mechanism for accurate and constant metering at the varying speeds and conditions, and adequate and proper vaporization, so that the mixture is homogeneous and sufficiently gaseous at all speeds and conditions. Both processes must be carried out in a constant manner and take place uniformly, irrespective of external conditions, such as summer or winter running and varying engine temperatures, speeds and loads.

To meet such requirements heat will undoubtedly be necessary, and any application of this nature must, of course, be under automatic control. Arrangements that depend for their success on the intelligent cooperation of the driver or any particular set of external conditions cannot be regarded as satisfactory from a commercial point of view. Schemes aiming at real economy must take note also of the preliminary warming-up period and also usage that embodies numerous starts and stops. These are the circumstances that at present give bad consumption figures. Further, this is the running that nowadays makes for rapid carbonization, crankcase dilution and so on, and heat in some form is vital, particularly in these conditions. Much vibration and rough running is attributable to carburetion. Correct distribution, at all speeds and conditions, is essential for uniform smoothness. The full extent of the relationship between distribution and consumption is not always fully appreciated.—*Automobile Engineer* (London).

CORN AND OATS

THE outlook for corn and oats prices for the next few years is not so good. Oats acreage in the United States has been increased by 4,000,000 acres since 1920, in spite of a lessened demand owing to decrease in horse population and in the face of falling values a continued decline in oats values is to be expected, unless acreage is reduced.

Corn values have been unfavorably influenced by oats prices, and the same decline in numbers of horses also directly lessens the demand for corn. A big influence in the corn supply and demand that is being actually felt is due to the advance in the knowledge of feeding and the greater efficiency in the production of pork, beef and other animal products.

The old ways of feeding requiring 11 or 12 bu. of corn to produce 100 lb. of hog, are giving way to a system based on new knowledge of the use of supplemental protein feeds and minerals, enabling the feeder to produce 100 lb. hog live-weight for 7 bu. of corn or less. This system increases hog profits, of course, but lessens the requirements for corn and hence tends to lower corn prices and indirectly, oats prices.

To a great extent also, supplemental feeds of protein and mineral ingredients have lessened grain requirements for production of beef, dairy and poultry products, mutton and wool. Acre yields of corn that have shown increasing tendencies for a number of years will remain on a permanent higher basis than formerly, on account of new varieties, increasing attention to soil improvement and better methods of culture.—C. S. Holmes, Iowa State Agricultural College.

FARM MACHINE INCREASE

THE Department of Commerce has published figures showing that on Jan. 1, 1925, tractors to the number of 506,745 were in use on farms in the United States, compared with 246,083 in 1920, an increase of 105.9 per cent. It is safe to assume that this rate of gain has continued up to the present time. The Department also reported that for the 3 years ended Dec. 31, 1925, farmers bought more than $1,000,000,000 worth of machinery.

These figures show that competition exists in farming as well as in steel making and automobile building. Those farmers who cannot survive must look to other lines, just as manufacturers and merchants do who can not compete successfully. All progress has had this result. Workers have been continuously thrown out of employment by improved methods of production. The reason the farmer has been comparatively immune from the effect of competition is that he has, until recent years, made little progress.

The result of this machinery movement will be to force more people into towns and cities. The farmer is making progress and because he is making progress he is making a problem. The solution will be to find new industries, new outlets for human energy. Just what industries will be evolved cannot, of course, be foreseen as the locomotive, the telephone, the motor-car, the moving-picture, the radio and the thousands of miles of improved highways could not be foreseen.—*Wall Street Journal.*

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The Electrodeposition of Rubber

By S. E. Sheppard[1]

Detroit Section Paper *Illustrated with* Photographs and Drawings

ABSTRACT

After giving a brief description of the nature of rubber latex and a review of investigations made in Europe of its physico-chemical properties, the author tells of experiments made in Rochester to develop a method for the electrodeposition of rubber particles. These proved that the process was possible but the problem of producing a coating containing all the ingredients requisite in a compound suitable for vulcanizing remained to be solved. The nature of the rubber particles and of rubber after coagulation of the particles is described and the method of rubber-plating as developed is explained.

It is stated that the deposit can be built up almost indefinitely and at a very rapid rate; that the composition remains substantially unchanged during coating, and that the current efficiency is remarkably high. Explanation is given of the electrochemical factors involved, which require that all the ingredients of the mixture be brought to approximately the same state of subdivision or size of particles as the size of the rubber particles so that they will mix uniformly with the latter, and that the rubber, sulphur, filler, dye and other constituents of the mixture be brought into a state of stable and like electrical charge. The nature of the electrode is of decisive importance. Use of a porous non-conducting diaphragm that surrounds the anode and is electrically connected with it is especially valuable, as the action of the diaphragm results in continuous deposition of the rubber, due to the fact that the side away from the anode becomes charged positively and the side adjacent to the anode becomes charged negatively.

If rubber is to be deposited on metal as a permanent covering, or if metal anodes are used for forming rubber products, a choice of various metals that behave differently as electrodes in rubber deposition can be exercised among three classes of metals, which are listed. Zinc is the most satisfactory metal, and the most promising procedure that has been developed is to give other metals a preliminary zinc-coating. Satisfactory adhesion of rubber to metal has been secured, and this opens a large and valuable field for the process.

The deposited rubber can be given almost any desired cure by vulcanization by varying the proportions of sulphur, fillers and accelerators in the mixture. Any stage of softness and elasticity up to that of hard rubber can be secured. Ultra-accelerators may be used which speed up the process at ordinary temperatures to such an extent that they cannot be blended on the rubber rolls.

Any available dyes can be used for coloring the product in the process of deposition, and a grain finish can be given mechanically while the rubber is in a plastic state before it is completely dry, or a natural grain may be left. Aging properties of the electro-rubber are superior to those of rubber made in the usual way.

To describe the process of electrodeposition of rubber, I shall have to precede the actual subject by a brief discussion of the properties of electrically charged suspensions and also by some reference to the nature of rubber and rubber latex. In the form in which we commonly meet it, rubber is a remarkably resilient solid, distinguished also by high electrical-insulating properties; therefore at first sight it is not a very promising material for an electrochemical process. But rubber originally appears in nature as latex, a milky or rather a creamy fluid that exudes from the inner bark of certain plants or trees when they are cut. Usually the latex is collected in open vessels and crude rubber is coagulated from this by a process that resembles somewhat the curdling of milk. The curd or coagulum is washed and sheeted mechanically at the plantations and is then exported in bales.

Fresh latex is an unstable material that rapidly undergoes a series of chemical and physical changes that lead to coagulation unless this is overcome by preservatives such as ammonium. Due to the fact that the chief rubber-producing plants are tropic growths, intensive scientific investigation has been made only recently on the properties of latex itself, although as early as 1830 Thomas Hancock, one of the pioneers of the rubber industry, was carrying out experiments on the industrial possibilities of latex. Microscopic observations show it to consist of a number of microscopic granules suspended in a watery fluid.

Not until 1906 and 1907 was a real fundamental physico-chemical research made on the properties of rubber latex. Investigations then made by Victor Henri, at that time assistant professor in the laboratory of physiological chemistry at La Sorbonne, Paris, contained the germ of the process of electrodeposition of rubber, and it was my good fortune to be working in Henri's laboratory at the time. Henri showed that the particles in latex were in constant Brownian movement, which will be described later, and further that latex behaved like a typical negatively charged colloid; that is, the particles were precipitated and coagulated by positively charged ions, and the effect increased with increase in the valency of the ion. The negative charge on the particles, already indicated by their reaction to positive ions, was more conclusively proved by Henri by demonstrating their transport in the electrical field. He showed that if the latex was diluted with water or weak ammonia and placed in a U-tube and a current passed between two platinum electrodes the rubber particles moved in the direction of the anode. This experiment forms the nucleus of the process of electrodeposition.

Many years later, when working in the research laboratories of the Eastman Kodak Co. on aqueous suspensions and emulsions, this experiment of Henri's came back to my mind. The question arose, If rubber particles in aqueous suspensions can be transported by the electric current, can they not be deposited electrically and, so to say, rubber-electroplated?

Other Materials Must Be Deposited Also

At that time it was very difficult to obtain samples of rubber latex. Van Rossem, director of the Netherland Rubber Institute, has pointed out that even in 1921, at the Fifth International Rubber Exhibition in London,

[1] Research laboratory, Eastman Kodak Co., Rochester, N. Y.

latex was still a scientific curiosity. As I was unable to procure rubber latex at once, I took up with L. W. Eberlin the production of an artificial rubber-latex, and we prepared stable rubber-emulsions from benzene solutions of rubber by emulsifying the rubber from these with ammonium soaps. We found that such emulsions and dispersions gave negatively charged particles. Further, the rubber was precipitated from such dispersions by positive ions, moved with the electric current toward the anode, and was deposited on an anode as a continuous film. The behavior was entirely parallel to that of natural latex, as we were able to demonstrate as soon as we secured some of this.

Although these experiments showed that electrodeposition was possible, the results were still a long way from a practical application. Rubber must be vulcanized to be useful. Such electrical coatings, if thin enough, might be vulcanized externally by the use of sulphur chloride or by other methods, but such processes have only a limited application. The essential requirement is that the rubber produced shall be similar to rubber compounds that have been developed by technologists since the discovery by Goodyear of the remarkable effects of heated sulphur upon rubber. This means that it must be possible to deposit electrically, together with the rubber particles, sulphur, mineral and organic fillers, accelerators, softeners and other materials according to various specific requirements.

Suspensions Must Be of Like Charge

The particles in natural rubber-latex and in well-made artificial dispersions are of the order of 1 micron in diameter, that is 0.001 mm. (0.00004 in.) more or less. It is necessary that the sulphur and other substances be brought to a comparable state of subdivision to be mixed uniformly with the rubber. But other conditions are requisite besides that of subdivision. The electric transport of suspended particles depends on the existence of the contact-potential between the particles and the liquid, which gives rise to a charge either positive or negative. If suspensions of opposite charge are mixed, within a certain zone of equivalent concentration, they will precipitate each other. Such unstable conditions must therefore be prevented in preparing mixtures of rubber latex with suspensions of sulphur, pigments, and so on. Sulphur is readily wetted by water and usually takes a negative charge, hence, no great difficulty exists in incorporating it with latex. On the other hand, certain fillers, notably insoluble oxides, tend to take a positive charge and must be stabilized, either by what is termed complex ion-formation or by protective colloids.

Structure of the Latex Particle

Before considering the deposition of complete rubber compounds, it will be well to return a moment to the structure of the rubber-latex particle and its bearing on the nature of finished rubber. Rubber itself is a hydrocarbon; a polymerization product, in natural rubber, of isoprene (C_5H_8). The latex particle is not homogeneous, however. Fig. 1 is a microscopic enlargement of particles from the commonest form of rubber latex, that from the Hevea grown on the plantations. Many of the particles are pear-shaped or have tails, and this is evidence that the hydrocarbon is in a solid or semi-solid state, since, if it were in a liquid state, surface tension would pull it into spheres. Recent investigations have shown that the inside of the rubber particle is in a much less solid condition, and is possibly liquid, while the outer hydrocarbon is solidified.

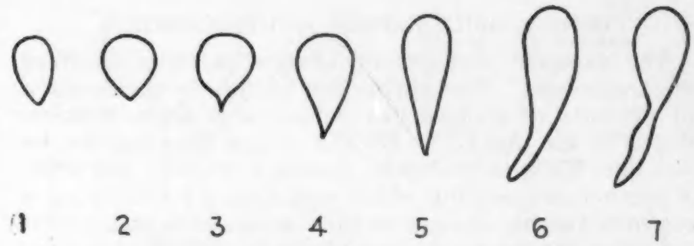

Fig. 1—Microscopic Enlargement of Latex Particles

Many of the Particles from Hevea Braziliensis Are Pear-Shaped or Have Tails, Which Is Evidence that the Hydrocarbon of Which the Particle Is Composed Is in a Solid or Semi-Solid State. Forms 4, 5 and 6 Are Most Common in Latex from the Normal Tapping-Area of the Tree; Forms 1 and 2, in Latex from New Branches, Leaf-Stems and Leaves; and Form 7, from Old Trees or after Certain Treatment of the Latex. Size of the Particles Varies from 0.0005 to 0.0045 Mm. (0.00002 to 0.00018 In.) Long Diameter

Fig. 2 is a diagrammatic cross-section of the Hevea particle. Outside of the rubber shell is a skin or film of closely adhering proteins, roughly analogous to albumin or casein. Recent work in the Goodyear laboratories has shown that this protein probably is held to the rubber simply as a layer about one molecule thick. Evidence also exists that the film is not absolutely continuous but rather is like a net stretched round a balloon. This film is of great importance in the technology of rubber.

When the latex particles are coagulated together, the strength of the resultant rubber depends on two factors: (*a*) the aggregation of the rubber particles themselves and (*b*) the nature of the inside of the latex particle. Roughly, the condition resembles somewhat that which determines the strength of metals, in which an assemblage of closely fitting crystalline grains or cells exists. The strength of the metal depends in part upon the relative size and fitting together of these grains and on the properties of the intergranular layer, but also depends very decisively upon the nature of the crystals themselves, that is, the arrangement of the atoms as determined by their chemical character. In this connection it is interesting to notice that recent work with X-rays has shown that in stretched rubber, from whatever source, the hydrocarbon molecules are definitely oriented in what we may call a crystalline or semi-crystalline way.

I shall not discuss further the important relation of this structure of rubber to its strength; it will suffice to state that electrodeposited rubber leaves the rubber particles piled together in close packing without mechanical injury.

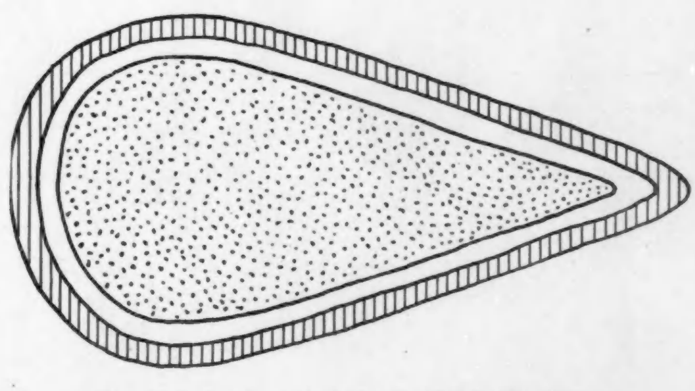

Fig. 2—Diagrammatic Cross-Section of Particle

Outside of the Rubber Shell Is a Skin or Film of Closely Adhering Proteins Which Probably Is Held to the Rubber as a Layer about One Molecule Thick. When the Latex Is Coagulated the Strength of the Rubber Depends upon the Aggregation of the Particles and the Nature of the Latex Particle. X-Rays Show that in Stretched Rubber the Hydrocarbon Molecules Are Definitely Oriented in a Crystalline or Semi-Crystalline Way

Deposit Built Rapidly and Indefinitely

The transport of electrically charged particles is termed electrophoresis. The application of this to the forming of deposits of compounded rubber was made independently by me and L. W. Eberlin in this Country, and by Dr. Paul Klein in Budapest, Hungary, in 1921 and 1922. A motion-picture film, which was made by combining a cinematographic camera with a microscope and photographing the movement and electrodeposition of rubber particles in a very thin film on the microscopic stage, gives a fairly clear idea of the action that actually occurs.

The electric circuit for plating rubber is fairly simple, as shown in Fig. 3. Direct current of from 30 to 50 volts is used, while the current density may be varied considerably, but is generally of the order of 1/10 to 1/3 amp. per sq. in. It might be supposed that, since rubber is essentially an insulator, the first thin film deposited would prevent further deposition by blocking the current, but the deposit as formed can be redispersed readily by reversal of the current, and the deposit builds up steadily as a layer of many particles superposed on one another. The fact is that the deposit is an uncoagulated reversible gel that contains a continuous film of fluid which is an electrolytic conductor; therefore, the deposit can be built almost indefinitely. The actual rate of deposition is very rapid and depends upon the voltage imposed and the current density used. An illustration of this is given in Fig. 4. Moreover, when a mixed rubber, sulphur and other ingredients are electrodeposited, the composition remains substantially unchanged during coating and the proportion of the components in the deposition is the same as that in the solution.

Although this is not desirable in practice, the electrodeposition of rubber can be continued until the bath is exhausted. The concentration affects the rate of deposition and means have been developed for securing constancy and uniformity of concentration during the process.

Current Efficiency Remarkably High

The current efficiency in the process is very high as compared with that in the electrodeposition of metals. This is a consequence of the fact that the mass of colloid or suspended particles relative to their charge is very high compared with that of an atomic or molecular ion. In early experiments on this plating from nearly pure rubber suspensions approximately 1500 grams of rubber and 2000 grams of a mixture of one-half rubber and one-half zinc oxide were deposited per farad. In later

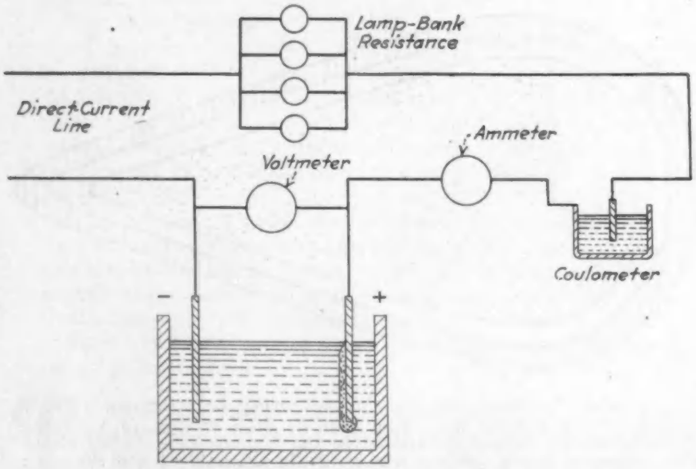

Fig. 3—Electric Circuit for Rubber Deposition
Direct Current of from 30 to 50 Volts Is Used and the Current Density May Be Varied Considerably but Usually Is of the Order 1/10 to 1/3 Amp. per Sq. In.

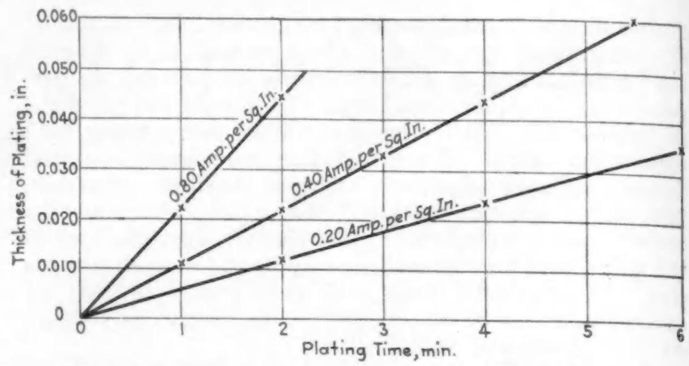

Fig. 4—Relation of Rubber Deposit to Plating Current
The Rate of Deposition Is Very Rapid and Depends upon the Voltage Imposed and the Current Density Used. The Curves Shown Are for a Voltage of 50 to 65 Volts

work considerably higher values have been obtained; namely, up to 4850 grams of rubber per farad, with a current efficiency of 0.02 kw-hr. per lb. This means that as much as 160 times the amount of rubber can be deposited as could be plated of nickel for the same amount of current, while a deposit 1400 times as thick as the equivalent nickel-deposit is obtained.

It has been stated that the gel originally deposited contains liquid which must be removed by drying before vulcanization. However, the amount of liquid remaining need not be more than 50 per cent of the solids and can be reduced to even less. It is removed readily by any of a variety of dehydrating processes.

The Electrochemical Factors Involved

Although electrophoresis has been distinguished from electrolysis, according to whether a suspension or a solution is involved, actually the processes are continuous with each other. Professor McBain has pointed out that the movement of charged carriers is identical with electrolytic conductivity. All carriers, whether ions or surfaces, must, therefore, impart conductance to the system, and the whole problem of electrophoresis is brought into the field of electrolytic migration. In every case the relative movement between solvent and carrier is involved, whether the relative movement be envisaged as electrophoresis, electro-osmosis, or ionic migration. The investigation of sodium-oleate sols, gels, and curds shows that the electrolytic migration in soap solutions consists of strictly identical processes with the electro-osmosis of water through a transparent soap-jelly and with the electrophoresis of pieces of soap jelly suspended in a soap solution. In each case the relative movement of, for instance, sodium and water is the same.

A general formula that expresses the actual movement relative to the solvent of each constituent of a system that is electrically conducting, whether it is homogeneous or heterogeneous, electrolytic, colloidal, or involves electrical double layers or diaphragms, is

$$n_1 = c_1 m_1 f_1 / \mu \quad (1)$$

in which

$c_1 =$ the concentration of this constituent in chemical equivalents per kilogram of solvent
$f_1 =$ the electrical conductivity per electrical charge, so that $m_1 f_1$ is the effective mobility
$m_1 =$ the number of chemical equivalents that carry one electrical charge, whether positive or negative
$\mu =$ the total conductivity of the solution and is equal to the sum of the concentrations of each conducting constituent multiplied by its mobility
$n_1 =$ the number of chemical equivalents transported per farad per current

The movement of the solvent relative to any conducting constituent is m_sf_i/μ kg. of solvent per farad of current and is termed electro-osmosis. From Formula (1) it will be seen that by reducing the conductivity due to electrolytic ions, the efficiency of transport and depositions of the suspended or colloid constituents will be increased.

Nature of Electrode Decisively Important

The foregoing refers primarily to the process of transfer of electricity and the transport of material. When the processes at the electrode are considered, the discharge of particles and ions involves certain unavoidable electrochemical changes. At the anode negative charges are transferred to the anode, and the nature of this electrode is of decisive importance. The principal conducting anion in the rubber suspensions, and the one whose absorption to the rubber particle probably gives it its electrical charge, is the hydroxyl ion. The discharge of hydroxyl ions is of chief importance. If simple discharge of hydroxyl ions occurs, oxidation phenomena are effected. Thus, oxygen gas may be generated and not only is there liability of oxidative attack on the rubber, but mechanical porosity and bubbles are produced, which gives an imperfect product.

Various methods that avoid this are available. Other anions that have a lower discharge-potential than hydroxyl ions and which give non-gaseous products may be present. Very useful are sulphhydrate ions and S_x ions, or polysulphide ions, which upon discharge give sulphur that is available for combination with the rubber. Another useful anion is the hyposulphite anion. Reducing agents, such as pyrogallol, that absorb oxygen, may also be present.

Another particularly valuable method, which was worked out by Dr. Klein and his collaborators, consists in the use of a porous non-conducting diaphragm surrounding the anode and electrolytically connected with it. Upon electrolysis of a rubber suspension, the rubber is deposited upon the diaphragm while the gaseous products due to discharge of hydroxyl ions are evolved upon the anode itself. This is illustrated in Fig. 5. The action of this diaphragm is similar to that of the rubber gel itself in allowing a continuance of rubber deposition. Any such diaphragm or membrane takes on a potential difference such that the side away from the anode is

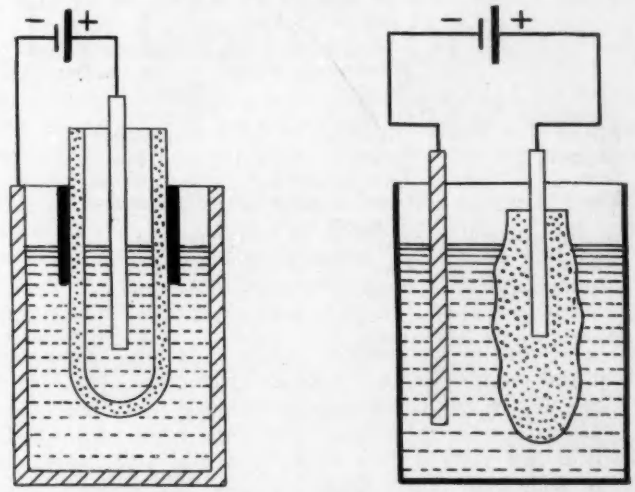

Fig. 5—Klein's Porous Non-Conducting Diaphragm
The Diaphragm Surrounds the Anode and Is Electrolytically Connected with it. Rubber Is Deposited upon the Diaphragm while Gaseous Products Due to Discharge of Hydroxyl Ions Are Evolved upon the Anode

positively charged and the side adjacent to the anode is relatively negatively charged. At the same time a relative increase of hydroxyl-ion concentration occurs which affects the surface of the diaphragm remote from the anode and results in an increase of the hydroxyl-ion concentration on the side adjacent to the anode. The increase of the hydrogen-ion concentration probably is partly responsible for the deposition of the rubber on the diaphragm. In some respects the phenomenon resembles the so-called electrostenolysis of metals, which consists in the deposition of metal in cracks through a non-conducting diaphragm when interposed in the electrodeposition of metals.

Use of Porous-Carbon Anodes

If we wish actually to deposit rubber on metal as a permanent covering, or to use metal anodes for forming rubber products, we can also make a selection or choice of the anode metal. For this purpose the metals may be divided electrochemically into three classes, in respect of their behavior as anodes, in electrolysis. The metals in Class *A* are completely attackable; that is, they pass into solution as metal cations, with formation of oxides

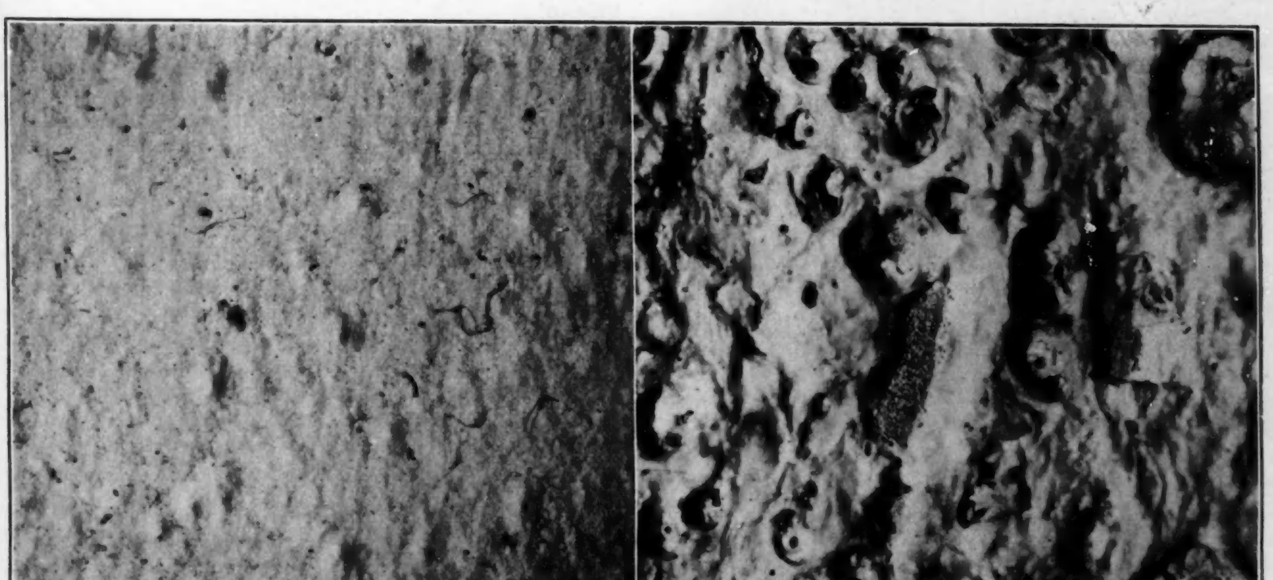

Fig. 6—Deposits of Rubber on Aluminum, at Left, and on Cadmium, at Right, Magnified 30 Diameters

TABLE 1—BEHAVIOR OF METALS AS ELECTRODES IN RUBBER DEPOSITION

	Character of Electrodeposition	Chemical Effect on Rubber
Zinc	Good	Useful
Cadmium	Good	Useful
Silver	Good	Harmless
Copper	Good	Destroys
Iron	Fair to good	Dangerous
Tin	Good in thin layers	Harmless
Platinum	Fair	Useful
Nickel	Poor	Unknown
Aluminum	Poor	Harmless

that are more or less soluble in the solution. Zinc, cadmium and magnesium are notable examples. The metals in Class *B* are not completely attackable and phenomena of passivity can intervene. In this class the anodic potential can vary widely with the metal and conditions of the solution. This class includes tin, copper, iron, nickel and chromium. In Class *C* the metals are only slightly attackable or nearly completely unattackable.

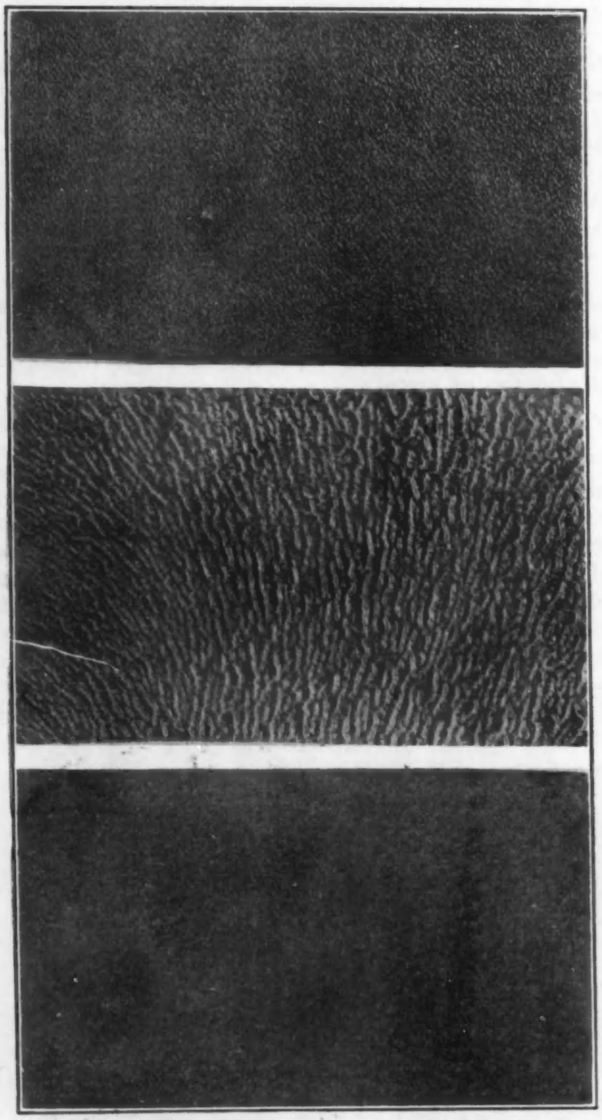

FIG. 7—NATURAL GRAIN OF ELECTRODEPOSITED RUBBER
Such Grains Can Be Left by Suitable Modification of the Electro-Osmotic Condition. Graining Can also be Done Mechanically on the Plastic Rubber before It Is Completely Dry

Platinum, palladium, iridium, gold, the so-called noble metals, are typical of this class and behave as irreversible oxygen electrodes. Practically, the behavior of metals as electrodes in rubber deposition is illustrated in Table 1.

SATISFACTORY ADHESION TO METAL SECURED

The general behavior shows that zinc is the most satisfactory metal and, while attention has been and is being paid to direct deposition upon other metals, the most promising procedure at present consists in giving the metal a preliminary zinc-coat, either by galvanizing or electroplating. The possibilities of deposition upon such zinc-coated metals are shown in Fig. 6.

It is comparatively easy to deposit rubber so that it will strip readily from the metal when dry, but it is not easy to deposit it so that it will adhere firmly after deposition, drying and vulcanizing. However, an adhesion has been secured that is satisfactory for many purposes where high mechanical strain is not involved and that is sufficient for many purposes, such as coating wire and other bodies of simple contours. Rubber that is to form a permanent coating upon metal usually does not need to possess the highest tensile-strength and elasticity. It is therefore a valuable feature of the process that not only high-grade rubber-latex, but also redispersed rubber-reclaim, may be used, and coatings of the latter are found to give adhesion more readily than pure rubber. The problem of securing the utmost adhesion of highest-grade rubber has not yet been solved but valuable progress has already been made. The advantages of the process for the continuous coating of wire, for protecting metallic surfaces, as in screens, and for resisting corrosion are definite. It is evident, therefore, that a large and valuable field lies open to the process as it becomes perfected.

VULCANIZING AND FINISHING NOT LIMITED

It is possible to produce almost any kind of known cure, by incorporating sufficient sulphur, fillers and accelerators. Rubber can be formed and cured to any stage of softness and elasticity up to the typical rigid and non-deformable hard-rubber. One aspect of vulcanization in which the electrodeposition process has a distinct advantage is that so-called ultra-accelerators can be used. These are substances that so speed up the process of vulcanization at ordinary temperatures that they cannot be blended on the rolls because the materials would begin to vulcanize and scorch. In our process, which is conducted throughout at low temperatures, these ultra-accelerators can be deposited and successful vulcanization effected during the final drying process at ordinary temperatures.

With regard to the finishing and appearance of the rubber, any of the available dyes can be used for coloring it, including dyes that are insoluble in water and are deposited with the rubber. Graining can be done mechanically on the plastic rubber before it is completely dry, or a natural grain may be left by suitable modification of the electro-osmotic condition, examples of which are shown in Fig. 7.

Finally, the aging properties of the electro-rubber, even without the addition of age-resisting compounds, are superior to those of rubber made in the usual way, yet such resisting compounds can be used to full advantage.

Transportation by Conveyor

By Paul Phelps[1] and N. H. Preble[1] Discussion of Production Meeting Paper

ALL discussion of this paper at the Production Meeting in Chicago last September was extemporaneous. The edited transcript of each speaker's remarks was submitted to him for approval or correction before its publication herein. The abstract that was printed in connection with the paper in The Journal for October, 1926, is reprinted below to assist to a better understanding of the discussion by those desiring to gather some knowledge of the subjects covered without referring to the complete text as originally printed.

ABSTRACT

CITING in outline seven fundamental operations that embody in principle the complex problems of production of the modern automobile, the authors explain how mechanical-handling systems can be utilized for the accomplishment of transportation or of assembly or of both combined in all these specified procedures. Various forms of conveyor are illustrated and their application to obviate handling-difficulties, to increase the speed of transporting parts and to augment the rapidity of assembly is described.

Reductions in cost due to conveyor installations in several types of automobile plant are discussed. In one instance, manual handling was superseded and the saving in labor cost paid for the installation of the equipment within a few months; in another, the avoidance of traffic congestion within the plant was an asset; in a third, a conveyor installation costing more than $80,000 fully paid for itself within 6 months and then saved $800 per day.

Difficulties presented by such problems as returning empty mill-trucks to their proper starting-point, combining transportation with assembly, conserving floor-space, and overcoming awkward conditions are mentioned, and details of how these hindrances were minimized are stated.

Points covered in the discussion of the paper include a statement of some of the difficulties in handling material caused by casters and their remedy, maximum turning radius of conveyors and the maintenance of conveyors subject to accumulations of paint.

THE DISCUSSION

Chairman Eugene Bouton[2]:—The thought uppermost in industrial-transportation problems has been the man-saving part of labor-saving functions. This one element alone already has effected great economies, but the broad principle of conveyors seems to be understood imperfectly and applied insufficiently. It is generally believed that the cost of most products is almost directly proportional to the cost of handling material. The material handling in the manufacturing of any product is the greatest item, with the exception of machining and other operations, that goes to make up the particular part or unit. In any industrial process the greater part of non-productive labor employed is in handling material. The possibilities for reducing cost through efficient material-handling are far greater than in any other branch of indirect-labor expense. Synchronized material-movement, the grouping of production processes and the balancing of operations are important principles in lowering manufacturing costs and, because material handling forms a large part of the manufacturing of any given part, it is the opinion of many production men that as much time should be devoted to coordination of its material-handling elements, so far as their relation to production flow is concerned, as is the time devoted to machine-tools and machine-tool elements.

What has been Mr. Preble's experience with the caster situation? Frequently, with all material-handling equipment, but especially with body-trucks, the caster situation becomes very annoying.

N. H. Preble:—The caster situation is almost universally unsatisfactory, particularly in a body plant where the bodies pass over a very long run during the process of building. I know of no solution to the problem, or of any fully satisfactory caster on the market at present which can be purchased at a price that the purchasing department seems to be willing to pay. I am inclined to think that sometimes the loss that can be caused through failure of casters is not fully appreciated. If the caster breaks, it is not the cost of replacing the caster that is important, it is the delay in production that may easily result, due to the breaking-down of a truck on the line. Some casters that are on the market and are equipped with roller-bearings in the axles and special bearings in the swivel probably will do the work, but they are expensive.

We have tried a number of methods of oiling casters such as using a channel track on which the caster runs so as to pass it through an oil-bath; that method oils the caster but it also oils the floor. We have tried also putting in oiling tubes on each side, with the caster operating a trigger device that creates pressure back of the oil and results in two streams of oil going down on the caster. This is somewhat better than the oil-bath, but it is unreliable. In most plants, caster oiling is a big problem, particularly the oiling of the axle itself. If the axle is not oiled, the wheel and the axle will freeze and run hard; also, the axle will cut the yoke of the caster.

Question:—What is the radius permitted in a vertical plane in the case of the monorail conveyor?

Mr. Preble:—The question cannot be answered by a single statement because it depends on a number of different things. In general, the radius should be just as large as the layout will allow. We sometimes get a layout that does not allow as large a radius as we would like to have. The smaller the radius is, the sharper is the bending of the chain and the greater is the component on the carrying trolley due to the tension in the chain. Therefore, in general, the lighter the chain pull is, the more sharply it can be bent. I know of one installation, a conveyor having approximately 200 ft. of chain, where the radius of curvature in the vertical plane was only 4 ft., but that would not be possible if that were a longer line. Probably the only way to answer the question would be to discuss each particular instance, determine what the chain pull is at that particular point, take into consideration the spacing of the trolleys, ascertain the resultant component on them and, from that, determine how sharply the chain can be bent. Where a sharp bend is required, the chain must be

[1] Mechanical Handling Systems, Inc., Detroit.

[2] M.S.A.E.—Supervisor of time study, Chandler-Cleveland Motors Corporation, Cleveland.

very flexible. Probably some one of the forged chains is most suitable to such use. We like to maintain a radius of not less than 15 ft. where we can. The conveyor will operate at a smaller radius but just how much smaller depends on the individual bend.

QUESTION:—When the conveyors are running, what is the maximum angle allowable?

MR. PREBLE:—So far as the conveyor chain and trolley are concerned they can run vertically. Ordinarily, the angularity allowable is dependent on the material that the conveyor is carrying. If handling a very wide piece and it is desired to hang it close to the trolley, the angularity will be determined by the interference of the corner of that piece with the chain. If the chain runs straight up it means that the load is carried out at right angles to the chain, which makes a somewhat bad twist in the trolley. If the load is light, that probably would not have to be considered.

QUESTION:—You twist the chain though, do you not?

MR. PREBLE:—No, the chain bends against the normal bend of the chain.

QUESTION:—Does that not bring severe wear on the pins?

MR. PREBLE:—Probably it does wear more than the normal operation of chain, but actual experience indicates that this is not a serious factor. The ordinary installation of chain is sufficiently over-sized as to allow it to wear out to a considerable degree before there is any trouble. The sand-blast line that I mentioned is the only line I know of with which we have experienced unsatisfactory chain-life. When there has been any chain replacement it has been due to a combination of factors. The sand-blast has a very serious effect on the chain, although probably the forged chain used in that instance operates better through the sand-blast than a combination or steel chain.

QUESTION:—What is the best method to handle installations where paint accumulates on conveyor chains and trucks or casters?

MR. PREBLE:—I cannot say that there is any "best" method. If practicable the chain can be cleaned by passing it through some sort of solvent. For instance, if the lacquer accumulates—the solvent would take care of the situation very well. Some installations have been made where the return chain passes through a "burn-off" and it works out all right. Any of those things are more or less expensive. I have seen many lines in body shops running through paint booths, and also through the old-type varnish-layouts, where no provision for cleaning the chain was made. The stuff just accumulates on it over long periods. Sometimes that causes trouble, particularly if the line is shut down for a few days; the chain gums up on the track, and it is almost impossible to start it again. When it is started again it does not seem to make much difference. It runs along just as before. If a hinge-dog has considerable paint on it, the dog will not drop back into position.

CHAIRMAN BOUTON:—What are the respective advantages of installing the kicker-dog on the chain and of installing it on the truck? Frequently, it is possible to put the kicker-dog on the truck and thus permit placing the the truck on the chain at any given point.

MR. PREBLE:—Probably that is a matter of personal preference. We have had experience with both conditions. It may be somewhat more expensive to put the kicker-dog on the truck than on the chain. In the two cases in which we did put them on the truck, they were not so satisfactory. They seemed not to operate as well as on the chain. If you have them on the chain, it means that the body or whatever the material may be is always spaced at the same interval, which possibly helps a little in controlling production. There certainly is no objection to putting the kicker-dog on the truck if for any reason it is more desirable to the individual plant man, and if the proper sort of dog is put on. The dog has to be heavy enough so that it will drop into place and it has to be strong enough so it will not be damaged when the truck is off the line. It has to be arranged so it will not drag on the floor and catch. I think probably the more general practice is to put it on the chain.

THE DECLINE OF PRICES

ATTENTION has been directed frequently to the unusual combination of business prosperity and declining commodity prices in the last year. Government price-tables indicate a decline of nearly 6 per cent in the average of wholesale prices during the year, bringing the general level to the lowest point since July, 1924. As indicated in the group classification of the Department of Labor's price-index, the principal weight of these declines has fallen in the farm products and miscellaneous groups. In the former the drop in cotton and wheat has been largely responsible for the lower totals, as many farm commodities such as corn, oats, butter, eggs, hogs, and cattle are within striking distance of or actually higher than a year ago. In the latter the decline in rubber has been a large factor. Non-agricultural groups also are all down with the exception of fuels, but in these groups the declines have been gradual and of orderly character. Metals and metal products are lower in relation to 1913 prices than farm products, and the food products group is above the average given in the table of prices for "all commodities."

The lower trend of prices is the natural result of a combination of circumstances, including large production, the general decline of world prices which reflects the passing of paper money standards and inflation, and the increasing efficiency of industry. Insofar as the decline is the result of the latter, its effects are beneficial, as it stimulates consumption and strengthens our world trade position. In viewing the price situation, to reflect that we have had no inflation of prices which would require drastic deflation is reassuring. Nor is there any likelihood of credit pressure to force excessive liquidation. With the possibility that the general level of industrial operations may be somewhat lower in 1927 than in 1926, a further easing of prices would be natural, but barring a let-down in business of unexpected proportions such declines should be gradual.

Real wages of labor stand at the highest levels in the history of the Country. One of the reasons, of course, why industry has been able to pay these wages without a commensurate advance in the price level is because production has likewise been tremendously increased by labor-saving devices. So long as wage advances are accompanied by corresponding increases in productivity per worker, they are sound and promote rather than retard prosperity. Obviously, however, a declining price-level greatly increases the difficulty of maintaining high wage-levels.—National City Bank of New York.

Commercial Possibilities of Rubber-Electrodeposition Process

By J. W. SCHADE[1]

DETROIT SECTION PAPER *Illustrated with* DRAWINGS

ABSTRACT

ACTUAL production-equipment for making rubber goods by the anode process has not been installed and studied to yield accurate quantitative data, but laboratory work has been begun in Akron, Ohio, and although some of the facts learned cannot be discussed by the author at this time, enough general indications have been secured to lead to belief that widely varied and valuable applications of the process will be made.

Factors that influence the commercial application of any process are enumerated and the properties of rubber that the technologist usually studies to determine its suitability for specific uses are listed. Thorough comparison of anode rubber with the milled product has not been made but confirmatory experimental evidence supports belief that the process must yield stronger and tougher material than do current methods of production. The reasons for this are explained.

Other advantages possessed by anode-deposited rubber are superior aging-properties, reduction in the quantity of material used, applicability to the process of dispersed reclaimed-rubber, reduction in size of plant and size and cost of equipment needed, lower labor and power costs, and reduction in waste of material.

The process will be applicable, it is stated, to the various processes of the present rubber-factory, such as making continuous rubber-sheet; forming continuous tubes in long lengths; impregnating fabric with rubber throughout its structure, part way through, or on one surface only; coating metal with a tightly adhering coat of rubber; forming rubber articles of various shapes with uniform wall-thickness or with varied thickness; and making rubber sheets that are thinner than the thinnest that can be calendered.

THIS process is our laboratory's newest baby and all the family delight in telling about the wonderful child. Vitally significant quantitative data are lacking, however, because little has actually been done in applying the process commercially. Moreover, I am not at liberty to discuss some of the important facts we have learned about this phase of the subject; problems that directly influence the cost and efficiency of a process are frequently not proper subjects for public discussion until they are fully solved. Enough general indications may be presented, however, to lead to the belief that widely varied and valuable applications of the process will be made.

A little less than 2 years ago Dr. Paul Klein, technical director, and Mr. Rechtnitz, then president, of the Hungarian Rubber Co., of Budapest, visited Akron to interest the company with which I am connected in the anode process. As a result of this visit, the company undertook to promote the development of this infant industry in America. We had not gone far with the plan, however, when certain documents emanating from the United States Patent Office appeared claiming that Dr. Klein was not the father of this industrial prodigy, as we had supposed, but that Dr. S. E. Sheppard was its paternal ancestor. It was decided, therefore, to entrust the child's development to an institution to be known as American Anode, Inc., and to be supported by the families of the two claimants to parenthood and by the godfather, our company. Laboratory work has been begun under the new arrangement and the initial factory-production is to be conducted by the B. F. Goodrich Co. of Akron. Associated in this work are Dr. Szegvari, who for 2 years had immediate charge of Dr. Klein's development in Budapest; one of Dr. Sheppard's former assistants who is experienced in the process; and technologists who are familiar with the compounding and manufacturing methods now followed in the rubber industry.

FACTORS THAT INFLUENCE COMMERCIAL APPLICATION

To gain commercial success any process must conform to certain economic principles. First, the goods produced must yield a service value commensurate with the selling price and with other goods of the same type on the market. It must be possible, also, to manufacture them at a cost that will permit their sale at a price, service value considered, which compares favorably with the selling price of other articles of similar kind. These two requirements can be met only by proper study of certain factors, the more important of which are: (*a*) quality of the product, (*b*) material cost of the product, (*c*) cost of buildings and equipment for the process, (*d*) labor cost, (*e*) cost of power, (*f*) amount of waste and its salvage value, and (*g*) applicability of the process to a variety of uses.

I shall try to show why we believe the anode process will, in many applications, conform more closely to economic demands than the older processes generally employed today in the manufacture of rubber goods.

Determination of the quality of material used in fabricating goods is of prime importance to every industry, whether it be the manufacture of clothing, automobiles, or pottery. Rubber is used for such a great variety of purposes that the rubber technologist usually studies not only the mechanical properties of his materials but the electrical and chemical properties as well. Some of the properties of vulcanized rubber-compounds commonly studied in a rubber laboratory are:

(1) Form of stress-strain curve
(2) Tensile strength
(3) Elongation at rupture
(4) Deterioration with age
(5) Hysteresis losses
(6) Resilience
(7) Resistance to tearing
(8) Resistance to abrasion
(9) Resistance to action of acids, alkalies, oils, and so on
(10) Resistance to diffusion of gases
(11) Electrical properties for insulation, such as (*a*) resistivity, (*b*) dielectric constant, and (*c*) phase-angle difference

[1] Director of laboratories, B. F. Goodrich Co., Akron, Ohio.

Besides these, the plasticity of unvulcanized mixtures and the rate of vulcanization are also of vital importance. We have not made thorough comparison of anode rubber with mill-mixed material as to any one of these properties for a wide range of compounds. Some of these properties have not been studied at all with anode rubber. Several comparisons have been started to determine what advantages one or the other method of processing may yield for specific service; but a really satisfactory answer cannot be secured until a new art of rubber compounding has been developed. In spite of repeated and unvarying indications that the mechanical properties of anode rubber are superior to those of mill-mixed material, the comparison is still not wholly fair to the anode process. We are sure that the compounding principles applicable to the present industry will frequently not yield the best results for anode rubber; a fundamental study of compounding for the new process must be made before the best results can be secured.

Three Reasons for Anode-Rubber Superiority

Confirmatory experimental evidence, however, supports three reasons which led us in the first stages of our work to the opinion that the anode process must yield stronger and tougher material than the current methods of operation. The rubber particles in the latex are not homogeneous; the outside of each particle is decidedly tougher than the center. The rubber latex is therefore a mass of particles that have relatively tough coatings and adhere together. This structure obtains also in coagulated latex which has not been milled in any way. When put on masticating rolls, however, the chains of particles are torn apart, the particles are ruptured and a marked change occurs in the structure of the rubber. Milled rubber is softer, stickier, and more plastic than unmilled rubber, while the anode rubber, as deposited, is tougher than either milled or unmilled rubber. This toughness of deposited articles makes it much easier to strip them from the forms in the uncured state without damage. Not only have these changes occurred in the unvulcanized milled product, but the rate of vulcanization will be slower and the physical properties of the vulcanized product will be deteriorated to some extent. Milling is an essential process in all rubber manufacture today.

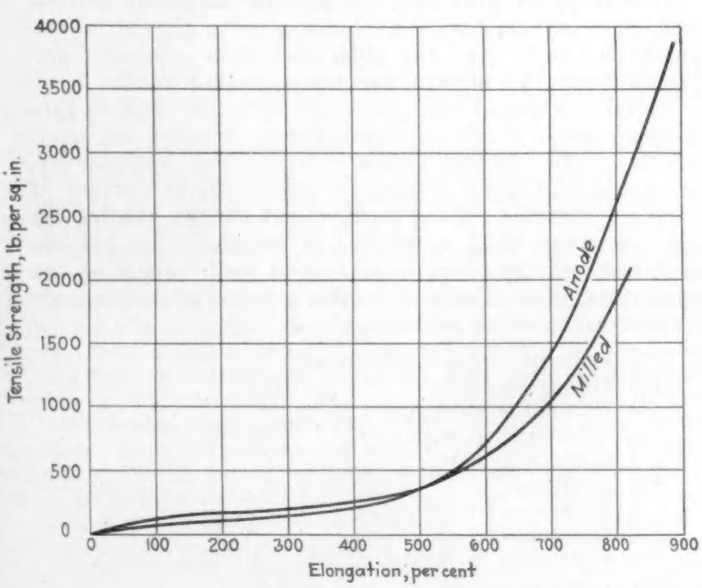

FIG. 1—STRESS-STRAIN CURVES FOR ELECTRODEPOSITED AND MILL-MIXED RUBBER COMPOUNDS

These Curves Show the Greater Tensile-Strength and Greater Elongation of the Anode-Deposited Compound, and Also the Greater Total Energy Required To Rupture It

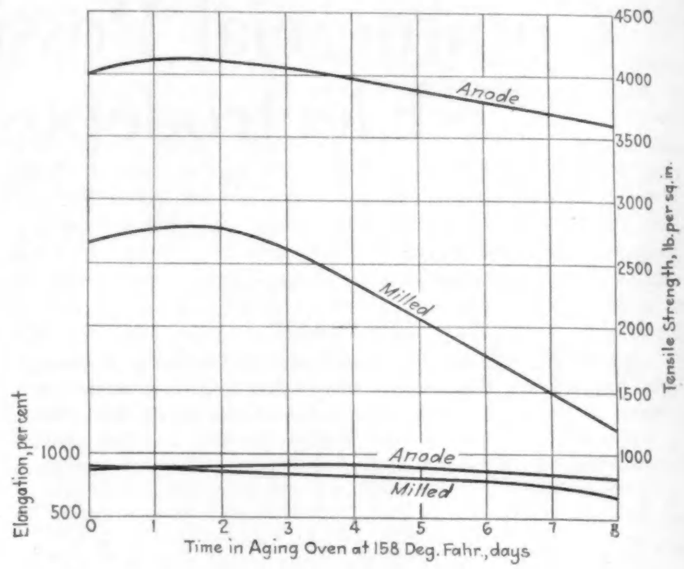

FIG. 2—RELATIVE AGING-PROPERTIES OF SIMILAR COMPOSITIONS MADE BY ANODE AND MILL PROCESSES

The Stocks Were Subjected to the Gier Aging-Process, Which Consists in Heating the Samples in Air at 158 Deg. Fahr. The Marked Superiority Indicated for the Anode Process Led to the Conclusion that It Will Yield Products Superior in Strength, Toughness and Aging Qualities to Similar Compounds Processed by the Usual Methods

It has long been recognized, also, that finely divided pigments give better physical properties in vulcanized rubber-mixtures than coarser particles of the same materials. Furthermore, the rubber manufacturer of today is limited in his use of powerful accelerators of vulcanization by the temperatures developed in mixing, calendering, or tubing. It is known that, in general, short periods and low temperatures of vulcanization improve the physical properties of the vulcanized rubber-mixtures. The anode process meets all of the three theoretical requirements. The rubber is not masticated, the pigments are fine enough to remain suspended in the water mixture, and powerful accelerators may be incorporated without danger of vulcanization before the desired article is formed.

To show the sort of difference that exists between the vulcanized products produced by the two methods, the stress-strain curves for a compound as mixed on a mill and as deposited by the current are plotted in Fig. 1. The increase in tensile strength, the greater elongation, and the increased total energy required to rupture the anode material will be noted.

The relative aging-properties of similar compositions made into sheets by mill mixing and sheeting and by anode deposition may be illustrated by the curves on Fig. 2. The stocks were subjected to the Gier aging-test, that is, heating in air at 158 deg. fahr., and the results again indicate marked superiority for the anode process.

Should Effect Saving in Material

We conclude, therefore, that the anode process will yield products much superior in strength, toughness and aging qualities to similar compounds processed by the usual methods. This is of great significance to the industry. What has been done in the field of metals and alloys may be repeated with rubber. Just as lighter, stronger and more serviceable structures have been made through the development of special steels, we look for

rubber products made by the anode process to yield better service with a marked saving in the quantity of material used. In 1926 the production of inner tubes in the United States reached the amazing total of about 76,000,000 tubes. Assuming that, by the use of the anode process, ½ lb. of rubber per tube, on the average, could be saved, we should thus conserve our rubber supply to the extent of 38,000,000 lb., or a little more than 4 per cent of the total amount of rubber imported last year. This, we believe, is not impossible, and by extending the saving to other lines of production it is reasonably conceivable that 10 per cent of our rubber may be saved.

Let me remove, also, any misconception that this method is applicable to depositing natural latex only. Rubber artificially dispersed has been deposited successfully, and mixtures containing dispersed reclaimed rubber have been formed into articles with improvement in quality over mill-mixed materials. We have found that by handling the reclaimed rubber in dispersed form the usual variability is surprisingly diminished.

Application of this principle of reduced volume of material to the design of rubber goods is evidently one method of lowering material costs. Moreover, we have reason to believe that rubber in the form of latex will eventually cost little, if any, more than sheeted or creped crude rubber as it appears on the market today. Concentrated latices that contain only 35 to 25 per cent of water, as compared with 60 to 65 per cent in natural latex, have appeared on the market. These concentrated latices may be diluted and used as latex and will, we believe, also tend to reduce the cost of rubber in latex form. However, even though there should be a slight increase in the cost per pound of material, in many instances the savings resulting from reduction of volume per article and from other features of the process will more than offset this. We may expect then, not only a better quality, but in most cases a lower article cost, also.

Expected Plant and Labor-Cost Reduction

The cost and size of a plant is reflected in the manufacturing cost of goods, by operating charges for rental or interest, depreciation, heating and lighting, amortization, and, to some extent, for maintenance. The cost of a plant to manufacture articles by the anode process will, we estimate, be less than is now required to manufacture rubber goods. We have no detailed figures to offer but simply contrast the type of equipment required for each. Today we find in well equipped factories a number of heavy high-powered machines and see considerable floor space given to storage of partly processed materials before they are ready to be formed into salable goods. We find rubber washing-mills, mixing-mills, warm-up mills, calenders, tube machines, cement churns, and spreading-machines. We find, also, large quantities of cloth wrappers, or so-called liners, and shells, or cloth-leaved "books," in which to store the partly processed material so that the sticky surfaces of the rubber or rubberized cloth will not adhere to one another.

Contrast the machinery mentioned, some of which requires special foundations, with that required for the anode process: colloid mills, tank mixers, deposition tanks. The relative cost of power equipment will be indicated in the saving in power. For rubber articles containing no fabric, cloth liners or books will not be needed, the machinery will require no special foundations, no industrial trucks will be required to transport materials from wash-room to dry-room, from dry-room to compound-room, and so on from step to step in the process, and floor space now used in storing materials in process will be greatly reduced. Space now required for forming articles by manual labor is, in certain instances, much greater than the space required for forming in deposition tanks. In some goods that contain fabric, considerable saving also will be possible. We conclude, therefore, that the lighter, cheaper machinery and the reduced floor space will present substantial economies for the new process.

Labor is costly. The whole trend of American industry for years has been to increase the output of each operator engaged in manufacturing processes by devising new processes, simplifying and changing the sequence of operations, eliminating superfluous handling of materials, making motion and time studies, and invention of automatic machinery. It is perhaps axiomatic to point out that the transportation of materials through pipe lines by gravity is cheaper than repeated loading and unloading of trucks and that the placing of materials by manual labor into molds and the building of articles manually on forms with tools for rolling, shaping, and trimming is more expensive than the deposition of materials on a group of forms by electric current. It may be axiomatic, also, to state that intermittent processes in which material is treated, transported and stored between separate operations are more costly than those in which subsequent operations follow one another and are automatically balanced as to the number of units or pounds produced and as to the time of completion of each step; or that in industry requiring skilled labor the labor turnover entails appreciable and sometimes serious increase in cost of production due to the necessity of paying the unskilled worker a living wage during his learning period. These are axiomatic; and because we see in the anode process the possibilities of easy application of mechanical controls to make processes continuous and automatic, the replacing of skilled labor with power, and the reduction of costly transportation of partly processed goods, we believe confidently it has inherent advantages over present processes.

Some figures that indicate a considerable saving in the power cost for mixing and depositing by the anode process as against the usual operations in handling materials by the present processes are given in Table 1. The figures for the old process are averages for 1 year's operation in the factory; those for the anode process are based on laboratory performance. By decreasing the first and increasing the second each 30 per cent to cover

TABLE 1—COMPARATIVE POWER-CONSUMPTION BY MILLING AND ANODE PROCESSES

Milling Process

Operations	Power Consumed per Ton of Dry Material, Kw-Hr. 90-Per Cent Rubber Mixture	50-Per Cent Rubber Mixture
Washing Rubber	301	167
Mill Mixing	460	460
Warming and Calendering	540	540
Total	1,301	1,167

Anode Process

Operations	Power Consumed per Ton of Dry Material, Kw-Hr. 90-Per Cent Rubber Mixture	50-Per Cent Rubber Mixture
Centrifuging Latex	8	5
Dispersing Pigments and Tank Mixing	86	225
Deposition on Zinc	180	100
Total	274	330

variations for differences in compounds mixed on mills and possible inaccuracy in the anode figures, an indicated saving of approximately 50 per cent still results. We may reasonably expect, then, a substantial reduction in power cost.

Probable Elimination of Waste

For almost every article made in rubber factories today a substantial charge for waste is allowed. When blanks are cut from uncured stock for molding or building on forms, some of the material must be remilled or recalendered before it can be used again. Cloth frictioned or coated with rubber and cut to definite shape or width entails waste of the rubberized fabric. This form of waste has less value than the fabric or the rubber would have separately. Many molded articles have rinds where the sections of the mold come together. These must be trimmed off and this vulcanized waste has even less value than the corresponding unvulcanized material. In building articles on forms it is often necessary to trim the stock, which is another source of waste. By the anode process it is possible, in many instances, to form articles without any necessity for trimming and with no unvulcanized waste except that which is spilled or coagulates naturally in the process, and by well regulated handling of the mixtures this has been reduced to a very small amount.

Many of the processes in use today inherently carry liability to waste in labor or material. Rubber varies in the time required to plasticize to a definite consistency on a mill. Reclaimed rubber, made as it is from scrap, necessarily varies in its physical properties. Powerful accelerators can be mixed without partial vulcanization on the mixing-mills only when great care is exercised. Because of the variability in raw materials and mixing temperatures, and of the human fallibility of the mill man, batch stock will at times be unsuited for subsequent operations and must be worked away at an increased labor cost and sometimes at reduced value for the material. The labor cost of running such defective stock through subsequent operations, such as tubing, may be increased. The number of feet per minute delivered from a tubing-machine may be reduced as much as 50 per cent by variation in batch stock.

Calendered stock will vary as to the proportion of suitable material it contains. Blisters, too great or too little tackiness of surface, variation in thickness, rough surface, too tightly stretched fabric, or scorching of the rubber compound are experienced in every rubber factory that uses calendered stock, and all of these defects cause reduction in material value or increased cost of handling or both.

For successful molding of articles the material must have a definite plasticity or flow in the molds, surfaces which flow together must flux and adhere, shrinkage must be controlled, especially in hard rubber; trapped air must be eliminated. Variations in the mixed or calendered material that is placed in molds results at times in poor flow and incompletely formed articles, in flow surfaces that do not adhere, in improper shrinkage, or in trapped air on the surface or in the structure.

While it is not assumed that the anode process will be found free from all difficulties of operation, it is rather definitely indicated that the structure of the deposit is more uniform than that of mill-mixed stock. It is possible to handle powerful accelerators without danger of scorching. Rubber can be deposited by the current to definite thickness. The surface of the deposit accurately duplicates the surface of the form on which the deposit is made, the outer surface is smooth, and the deposit, when properly dried and then cured, is absolutely without porosity. In general, many of the process defects that are now encountered are eliminated by the newer process, and, as yet, no serious difficulties in handling have been indicated. No vulcanized waste occurs such as now prevails in most molding processes.

We have good reason to believe that in some instances fabric may be cut to shape and only the portions that are to be used may be rubberized without distortion of the fabric. The salvage value of the fabric is, therefore, enhanced and the rubber material now included with the fabric in the cut waste entirely eliminated.

Uses to Which Process Is Applicable

The anode process will be applicable to the various processes of the present rubber factory. The making of continuous sheet, or electrophoretic calendering, if you will, is feasible; the forming of continuous tubes in long lengths, though more difficult, seems capable of attainment, if required; the impregnation of fabric with rubber throughout its structure, or part way through, or on one surface only, has already been secured on a laboratory scale. The coating of metal surfaces with a tightly adhering coat of rubber is not merely a dream; experiments indicate that it will be a practicable reality. The forming of rubber articles of various shapes, either of even wall-thickness throughout or of varied thickness in different parts of the same structure, has already been performed. Where extremely thin coats of rubber are desired this process seems to offer the best method of production of any yet suggested. Sheets can be made much thinner than the thinnest that can be calendered. It seems certain that articles now made by the dipping process can be made of better quality by the anode process and more economically, principally by saving in equipment and floor space and by elimination of solvent losses.

One other advantage in the matter of applicability should be mentioned. Anyone who now requires rubber articles in small quantity as parts of other equipment or for some specific technical use cannot afford to install standard rubber-machinery for making his limited production. The smallest standard machines for carrying on the various operations have a capacity far beyond his needs and he is faced with a high installation-cost and with having his machines and motors idle much of the time. He finds that rubber manufacturers are interested mainly in large-scale production of standard articles and can supply his requirements only at a cost altogether out of proportion to his desires. We believe that many demands will arise for rubber articles that can be made economically by the anode process with relatively cheap machinery operated economically without long periods of idleness.

We have reason to believe that the anode process, then, is applicable to the production of many completely formed and finished articles and many of the partly processed materials that are now produced in the rubber industry. It probably can be applied, also, to small-scale production more easily than the smallest present standard equipment permits.

Question may be raised as to the relative merits of the anode process and other processes in which the rubber compositions are deposited from suspensions upon porous forms by suction. We do not feel it possible to make a fair comparison at this stage of the development of the two processes. Both are new and both will be improved greatly as experimental work progresses. Each will

ultimately be applied to those uses for which it is eminently fitted. It appears now, however, that the anode process has undoubted advantages for certain purposes such as the production of inner tubes or the covering of metal with firmly adhering coatings.

To summarize, we believe that many useful applications of the anode process will be made, for the reasons given, which are:

(1) Improved quality of product
(2) Consequent saving in material
(3) Lower equipment and plant cost
(4) Lower labor-cost resulting from (*a*) the use of power in place of manual labor, (*b*) the reduction in the amount of skilled labor required, and (*c*) the continuous nature of the anode process as contrasted with the present discontinuous processes, and the introduction of automatic control of processing
(5) Lower cost of power per pound of rubber articles produced
(6) Reduced waste and enhanced value of whatever waste is entailed
(7) Applicability of the process not only to the present requirements of rubber manufacturers but to new uses and to economical small-scale as well as large-scale production

"SEA AUTOMOBILES"

SLOWLY and steadily steamships are disappearing from the high seas and their places are being taken by automobiles of the ocean; clean efficient motor-driven ships. Oil began by revolutionizing the generation of steam in marine boilers; it now has rendered that process obsolete because of its superior efficiency in the internal-combustion engine. Some 30 years ago the steamer commenced to displace the sailing ship.

Many people watched the arrival in New York Harbor recently of a large motor-driven liner prior to an extensive cruise including a complete circle of the African continent. This was the Royal Mail Steam Packet Co.'s Asturias, of 22,500 gross tons, which was driven at over 20 m.p.h. by huge twin sets of engines delivering a total of 15,000 hp. to the propellers. An entirely separate group of engines drives electric generators supplying current for every auxiliary service on the ship. This miniature power-station has an electrical output sufficient to supply a small town; which, in effect, it does. Although the Asturias is at present the largest existing ship in commission that is driven by internal-combustion engines, others are already on their way which will outstrip her not only in size but in power. Before this year is over, the laurel wreath probably will have gone to Italy, in whose shipyards a supership of 33,000 gross tons with engines delivering 28,000 hp. was recently launched. Plans have been prepared for a motorship of 40,000 hp. at the propellers.

The motor-driven ship had begun very slightly to influence shipping in 1912 when the Selandia, the first ocean-going motor-propelled freight and passenger ship, left Copenhagen, Denmark, on her maiden voyage to the Far East. Development in the war period was confined in great measure to neutral countries and in particular to Denmark, which has often been called the home of the motor-driven ship. The firm of Burmeister & Wain in Copenhagen has supplied the majority of engines for the present large fleet flying the Danish flag, and both directly and through its licensees has powered more motorships than any other builder of internal-combustion engines The greatest achievement of the Burmeister & Wain organization, in conjunction with the British shipbuildng firm, Harland & Wolff, is the construction of immense double-acting engines, developng up to about 1000 hp. in one cylinder, which are now being used to power large passenger and mail-liners. These engines have eight cylinders each of 33-in. diameter.

When we consider that the Selandia of 1912 needed eight cylinders to develop barely 900 hp. and that these had a diameter of only 21 in., we realize what tremendous progress has been made in the short space of 14 years. At present almost as many motor-driven ships are under construction in the world's shipyards as there are steamers.

The first large automobile of the sea, built especially and exclusively for passenger and mail carrying, operates between Vancouver, B. C., and Sydney, N. S. W., via Honolulu, Suva, Fiji and Auckland N. Z. She is the graceful and handsome Aorangi and was completed early in 1925 in a well-known Glasgow shipyard of international repute. Her construction was in every sense of the word pioneer work, especially in view of the long and arduous service for which she was intended.

The Aorangi was followed in the fall of 1925 by the Gripsholm, a Swedish owned vessel, now operating regularly between Gothenburg, Sweden, and New York City. This motorship is most luxuriously fitted. Large double-acting engines of more than 13,000 hp. give this ocean greyhound a speed of about 20 m.p.h. Passengers can now motor from Southampton, England, to Cape Town on Carnarvon Castle, a new oil-engined flyer of the Union Castle Mail Steamship Co.; and powerful motor-driven liners link Liverpool with West Africa. All these vessels were built and engined by Harland & Wolff, the Glasgow and Belfast shipbuilding firm. It will be interesting to see if the next Olympic or Majestic is a motorship.

In a short time we shall be able to "motor" to practically every known port in the world. We are promised a motor-driven liner in the late fall to run between New York City and Bermuda. Winter tourists are now motoring round the Mediterranean in a luxurious yacht. We can motor from Kobe to Beppu, across the beautiful inland sea of Japan, even the prosaic, stormy North Sea now has its small motor-liners. They are all pioneers, heralds of progress to come. —A. C. Hardy in *New York Herald Tribune.*

TRANSPORTATION OF PETROLEUM PRODUCTS

HARDLY a mile of our 265,000 miles of main-line railroad track does not have petroleum or petroleum products move over it, and to this we add over 70,000 miles of pipe lines which are devoted exclusively to this service. Approximately 153,000 railroad tank-cars are utilized to transport oil. The carload movement of petroleum and its products by Class-1 railroads in 1925 aggregated more than 1,951,000 carloads, or 5½ per cent of the total carload traffic originated. The demands of the petroleum industry for increased freight transportation service is shown by the fact that shipments of petroleum and its products in the year 1925 exceeded by 55 per cent the shipments of 1,258,000 carloads that originated in the year 1920, which was a year of great business activity and heavy traffic. Shipments of such freight in the first 6 months of 1926 exceeded similar shipments that were made in the corresponding period of 1925 by 5.2 per cent.—W. B. Bartel, before American Petroleum Institute.

THE MACHINE-TOOL INDUSTRY

OF all essential industries, the machine-tool industry is the prime essential. To all the key industries, it is the master key. In view of this, for an industry of such fundamental importance not to have been essentially profitable, or even prosperous is somewhat paradoxical. Great fortunes have been made in many industrial fields depending upon the machine-tool for its equipment, but comparatively few fortunes have been made in the machine-tool industry itself. Obviously, this industry must have peculiar and unusual factors that are responsible for this.

The machine-tool industry differs essentially from most other industrial enterprises for a number of reasons. Three of these are: (*a*) the extreme fluctuations in the demand for the product of the industry, (*b*) the great cost of development work and (*c*) the keen competition due to the comparatively small amount of capital required to enter this field in a small way.

The machine-tool industry is seasonal to a much higher degree than any other industry. Its "seasons" are generally not counted in months but in years. This industry may be very active for 1, 2 or, perhaps, 3 years, then it enters upon a period of slack business that can be characterized only as a depression, because of its severity, which may last anywhere from 2 to 3 years. The products of the machine-tool industry are in great demand only when other industries are in a state of expansion. Such periods of industrial expansion come only occasionally.

For machine-tool plants that operate to capacity one year to reduce their operations to from one-third to one-half of their normal capacity the next year is not unusual. In the latter part of 1919 and the early part of 1920, for example, practically every machine-tool plant in the United States worked to capacity. In 1921 and 1922 many plants operated at only from 15 to 30 per cent of capacity, and even in 1923 and 1925, considered as comparatively fair machine-tool years, many plants that operated at capacity in 1920 were able to find employment for only from 50 to 60 per cent of their capacity. Profits made in good years are absorbed by the losses in poor years, and the return on the capital invested spread over a period of years is probably smaller in the machine-tool industry than in almost any other industrial field of equal magnitude.

Many machine-tool firms under the pressure of competition, have had to spend practically all their profits in producing improved models. By the time they are able to realize some profits on these improved machines, they frequently find it necessary, on account of improvements made in the equipment of their competitors, to continue this cycle of development work, without much chance of ever realizing any substantial returns on the investment in the new models.

Machine-tools are seldom required in sufficient quantities to permit of quantity production methods in the machine-tool plants. In many machine-tool shops, 25 machines of one size is considered a large order, and in most plants 50 or 100 machines of one size, built at one time, are out of the question. Opportunities for the use of cost-reducing production machinery in the machine-tool builder's own plant are very few. The very conditions of his industry prevent him, in many cases, from using the efficient machines of his own manufacture.

A machine-tool shop can be operated with a fair measure of success on a very small scale and as a result new competition is constantly entering this field, especially during periods of industrial expansion when the established plants are well occupied and competition, therefore, is not so keen. When the curve of demand enters upon its downward trend, however, the competition becomes extremely keen, because of the share of business that the new arrivals in the industry obtain, with the result that almost always when the industry enters upon a period of depression, a number of the companies engaged in the machine-tool building industry are forced out of business. This condition was especially noticeable during the years 1921 to 1924, inclusive.

DISTRIBUTION OF THE MACHINE-TOOL INDUSTRY

As we all know, the center of population is moving westward. According to the 1920 census, it is located in the southwestern section of Indiana. It moved about 8 miles westward from 1910 to 1920. The center of the machine-tool industry has also constantly been moving westward during the last 50 years.

In 1899 the total value of the metal-working machinery built in the United States was about $25,000,000, of which machine-tools represented $18,000,000. Census figures are not available showing the total value of the products of the machine-tool builders in 1918 but an estimate may be based upon the total number of men employed in the industry in 1918, approximately 77,000, from which the total value of the machine-tools built in that year can be assumed to be between $300,000,000 and $400,000,000.

In 1921, a year of very severe depression, machine-tool production as a whole was only 30 per cent of what it was in 1919. In 1923 production was somewhat more than 50 per cent of what it was in 1919 and nearly double what it was in 1921. This is the last year for which complete machine-tool statistics are available.

If one were to attempt to locate the center of the machine-tool industry in the United States in the same way as the center of population is located, one would find it approximately on a line passing north and south just west of Buffalo. Slightly more than one-half of the machine-tools in the United States are built in New England, New York, New Jersey, Maryland, Delaware and Pennsylvania; very nearly one-half are built in Ohio and in the States west of Ohio.

The difficulties of the machine-tool industry due to the fluctuations in the business and the high cost of development work which consumes a large portion of the profits of the industry, can be remedied only by making the prices of machine-tools commensurate with all the expenses and business conditions incident to this industry. Proper cost-systems are the first essential and after that a more accurate conception of what are adequate returns in an industry that has several lean years interspersing the years of fair business.

Proper "pricing" of machine-tools would also permit this industry to pay adequate wages to its highly trained mechanical staff and to its highly skilled labor. That skilled toolmakers are paid not much more than half of what some of the men engaged in the building trades get is not to the best interests of the development of the machinery industries of the Country; yet the machine-tool builder has, in the past, been unable to remedy this condition, because of the inadequacy of his own returns from the business.—Erik Oberg, editor of *Machinery*, in *Trade Winds* (Union Trust Co. of Cleveland.)

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 10, and March 10, 1927. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ANDERSON, W. R. (A) development engineer, Manhattan Rubber Mfg. Co., Passaic, N. J.; (mail) 5221 Oregon Avenue, *Detroit.*

BABOR, RUD J. (M) chemical engineer, Ethyl Gasoline Corporation, New York City; (mail) 409 East High Street, *Bound Brook, N. J.*

BAKER, ARTHUR HAROLD (A) transport maintenance superintendent, Lago Petroleum Corporation, *Maracaibo, Venezuela.*

BLACKWOOD, ALBERT J. (J) mechanical engineer, International Motor Co., Long Island City, N. Y.; (mail) 4046 78th Street, *Jackson Heights, N. Y.*

BRANDERS, HANS ALEC (J) mechanical engineer, Borga Boatbuilding Co. *Borga, Finland;* (mail) Villa Anas.

BRILL, HERBERT C. (J) draftsman, Locke & Co., *Rochester, N. Y.*

BURKE, J. W. (A) production department garage superintendent, Shell Co. of California, *Long Beach, Cal.;* (mail) 2040 Orange Avenue.

CASTLE, CHARLES C. (A) vice-president, American Car & Foundry Motors Co., 30 Church Street, *New York City.*

CHAMBERLAIN, R. N. (M) research engineer, Gould Storage Battery Co., New York City; (mail) 32 West Randolph Street, *Chicago.*

DAVIDSON, G. W. (F M) director and works manager of the mechanical transport department, Ministry of Communications, *Cairo, Egypt.*

DUCKWORTH, R. G. (A) general service manager, General Motors Truck Co., 205 Ivy Street, *Atlanta.*

FREERS, GEORGE H. (M) assistant chief engineer, Marmon Motor Car Co., *Indianapolis.*

GOBBATO, UGO, (F M) mechanical engineer, Fiat Automobili, Turin, Italy; (mail) Via Mentana 24, *Turin,* (107) *Italy.*

GORDON, L. O. (M) president and manager, L. O. Gordon Mfg. Co., Larch and Seventh Streets, *Muskegon, Mich.*

GRACE, JAMES W. (A) superintendent of maintenance and repair of mechanical equipment, California Highway Commission, *Willits, Cal.;* (mail) 98 Commercial Street.

GREENEBAUM, CHARLES L. (A) president, Metropolitan Distributors, Inc., 625 West 49th Street, *New York City.*

GROVER, ROSS D. (J) draftsman, Republic Motor Truck Co., *Alma, Mich.;* (mail) 109 Walnut Street.

HILGENBERG, R. J. (M) bumper engineer, Bossert Corporation, *Syracuse, N. Y.;* (mail) 218 Helen Street.

HORTON, WILLIAM M., JR., (M) factory manager, Lamson-Sessions Co., Cleveland; (mail) 1557 Clarence Avenue, *Lakewood, Ohio.*

JACKSON, S. B. (A) sales engineer, General Electric Co., Schenectady, N. Y.; (mail) 700 Antoinette Street, *Detroit.*

JOHNSON, GEORGE, A. (M) New York City branch manager, North East Service, Inc., 355 West 52nd Street, *New York City.*

KUNS, RAY F. (M) principal, Automotive Trades School, Madison Road and Erie Avenue, *Cincinnati;* editor, *Automobile Digest,* Cincinnati; (mail) Automotive Trades School.

LOCKETZ, JACOB (J) machine designer, Imperial Machine Co., *Minneapolis;* (mail) 1615 Thomas Place, North.

MCCLELLAND, J. HAMPTON (A) salesman, C. G. Spring & Bumper Co., Detroit; (mail) 1906 Pinecrest Drive, *Ferndale, Mich.*

MONTGOMERY, SIDNEY (A) automotive service department, J. G. Brill Co., *Philadelphia;* (mail) 3539 Locust Street.

MOREE, K. EARL (M) assistant chief engineer, J. I. Case Plow Works, Inc., *Racine, Wis.*

NORVIEL, HARRY E. (M) engineer in charge of switches; circuit breakers and accessories, Remy Electric division of the General Motors Corporation, *Anderson, Ind.;* (mail) 1007 Arrow Avenue.

ORD, MALCOLM L. (M) president, Universal Machinists, Inc., 1136 Broadway, *Denver.*

PATTON, FRED C. (M) assistant manager, Los Angeles Motor Bus Co., *Los Angeles;* (mail) 4504 Willowbrook Avenue.

PLIMMER, ALFRED G. (M) machine designer, National Carbon Co., *Fremont, Ohio;* (mail) 202 North Wood Street.

PRITCHARD, W. S. (M) experimental engineer, Motor Products Corporation, Detroit; (mail) 1221 Lakepointe Avenue, *Grosse Pointe Park, Mich.*

PYLES, RUSSELL (J) principal aeronautical draftsman, National Advisory Committee for Aeronautics, Langley Field, Va.; (mail) R.F.D. No. 4, Box No. 12, *Hampton, Va.*

RAYMOND, L. R. (A) manager, Sterling Motor Truck Co., Ninth and Castro Street, *Oakland, Cal.*

RICHTER, LUDWIG, DR. ING. (F M) mechanical engineer and assistant to technical director, Oestreichisch Automobil-Fabriks-Actiengesellschaft vormals Austro Fiat, Vienna XXI, Austria; (mail) Seisgasse 9, 111, *Vienna IV, Austria.*

RINEHART, C. R. (M) vice-president, Overman Cushion Tire Co., 250 West 54th Street, *New York City.*

RUTTEN, CAPT. PAUL G. (S M) Ninth Motor Transport Co., Presidio, *San Francisco.*

SALTUS, R. SANFORD, JR. (A) vice-president, Ludington Exhibition Co., 816 Atlantic Building, *Philadelphia.*

SCHOLZ, W., DR. ING. (M) technical director, Reichsverband der Automobilindustrie, Behrenstrasse 63, *Berlin W. 8, Germany.*

SMITH, ALFRED C. (M) body engineer and general manager, Harvard Auto Body Co., Inc., *New York City;* (mail) 53 West Tremont Avenue.

STURGEON, GORDON M. (A) garage foreman, Peninsula Rapid Transit Co., Burlingame Cal.; (mail) 458 Natoma Street, *San Francisco.*

SWALM, ROBERT A. (M) treasurer and manager, Schuylkill Motors Co.; Schuylkill Motors Transportation Co., *Pottsville, Pa.;* (mail) 370 South Center Street.

TANNER, HUBERT D. (M) manager of gear division, Pratt & Whitney Co., 436 Capitol Avenue, *Hartford, Conn.*

THORN, WRAY T. (M) 5730 East Washington Street, *Indianapolis.*

UNDERWRITERS' LABORATORIES (Aff) 207 East Ohio Street, *Chicago*
Representative: Becker, George D.,
assistant engineer, casualty and automotive department.

WATERS, GUY WILLIAM (A) district sales manager, Timken Roller Bearing Co., Canton, Ohio; (mail) 7026 Euclid Avenue, *Cleveland.*

WERNER, WILLIAM (F M) manager of manufacturing, Horckwerke, Actiengesellschaft, *Zwickau, Saxony, Germany;* (mail) Robert-Blumstrasse 6.

WILLARD, JOHN RODERICK (J) apprentice engineer, Aluminum Co. of America, 2210 Harvard Avenue, *Cleveland.*

Vol. XX April, 1927 No. 4

Applicants *for* Membership

The applications for membership received between Feb. 15 and March 15, 1927, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABELL, CARL, advertising manager, American Car & Foundry Motors Co., *New York City.*

ALBAUGH, W. M., secretary, Thompson Products, Inc., *Cleveland.*

ALFOTH, H. A., service manager, General Motors Export Co., *New York City.*

ANDERSEN, A. C., automotive engineer, Shell Co. of California, *San Francisco.*

BAXTER, ROBERT HENRY, secretary-treasurer, Knight Rebound Controllers, Ltd., *Hamilton, Ont., Canada.*

BISSETT, EARL F., chief engineer, Anderson Engine Co., *Chicago.*

BOTTS, EDISON, assistant field engineer in tire development department, United States Rubber Co., *Detroit.*

CARLSON, ALBEN F., assistant body engineer, Pierce-Arrow Motor Car Co., *Buffalo.*

CARROLL, E. L., advertising representative, Society of Automotive Engineers, Inc., *New York City.*

COLE, DEWEY, owner, Dewey Cole Garage, *Iowa Park, Tex.*

COWDREY BRAKE TESTER ORGANIZATION, *Fitchburg, Mass.*

DAMMANN, WILL, president, Bear Mfg. Co., *Rock Island, Ill.*

DE HART, CHARLES R., JR., engineering department, Spicer Mfg. Corporation, *Plainfield, N. J.*

DE MARCO, GEORGE, foreman of electrical department, Public Service Transportation Co., *Newark, N. J.*

DIXON, ARTHUR, merchandise broker, Earl M. Hunker & Arthur Dixon, *Indianapolis, Ind.*

DOODY, EDMUND R., service supervisor, General Motors Truck Co., *New York City.*

DORMAN, J. R., president, Dorman Automotive Parts Co., *Cincinnati.*

FISHER, MILTON, mechanical superintendent, Morris Draying Co., *Oakland, Cal.*

FITZ, EARL M., assistant automotive superintendent, Shell Co. of California, *Los Angeles.*

FREEDLANDER, A. L., factory manager, Dayton Rubber Mfg. Co., *Dayton, Ohio.*

FRENCH, GERTHAL, manager of lubricating department, Sinclair Refining Co., *New York City.*

GOW, WILLIAM G., general service manager, Studebaker Sales Co. of Newark, *Newark, N. J.*

GRAF, ANDREW J., chief engineer, United States Motor Truck Co., *Cincinnati.*

GREENE, DONALD, road mechanic, Gardner Motor Co., *St. Louis.*

GREENE, MARIUS, technical adviser, Commuters Air Transport, Inc., *New York City.*

HALL, EDWIN SYDNEY, mechanical engineer, Bureau of Mines, *Rifle, Colo.*

HARRIS, MANSE M., general manager, Mackay Austin Valve Co., *Oakland, Cal.*

HENZE, OTTO C. W., mechanical engineer, Trans-Lux Daylight Picture Screen Corporation, *Brooklyn, N. Y.*

HUEP, FRED, designer, E. P. Hurd, *Detroit.*

JUENGST, EDWARD G., technical apprentice, White Co., *Cleveland.*

KASTENGREN, FOLKE K. A., production manager, General Motors Uruguaya, S. A., *Montevideo, Uruguay.*

KAUFFMAN, RAY, Accurate Gear Co., *Springfield, Ohio.*

KAUFFMAN, STANLEY, president and general manager, Accurate Gear Co., *Springfield, Ohio.*

LAMBERTON, DONALD C., chief inspector, Moto Meter Co., *Long Island City, N. Y.*

LANGLANDS, ERIC, chief engineer, Majestic Car Corporation, *City of Washington.*

LAPORTE, N. EMILE, engineer in charge of experimental department, Wright Fisher Engineering Co., *Montreal, Que., Canada.*

LUNDT, ERNEST C., engineering assistant, Consolidated Gas Co., *New York City.*

LYNN, W. D., planning and service manager, Maccar Corporation, *Scranton, Pa.*

MCGONAGLE, T. L., president, Denver Gear & Parts Co., *New York City.*

MATHEWS, J. A., president and general manager, Mathews Steel Castings, Inc., *Chicago.*

MEDORE, O. A., research engineer, *Dunbar, Pa.*

MORRISSEY, G. F., secretary-treasurer, Northwest Bearing Co., *Seattle, Wash.*

OGBURN, CARL, superintendent of maintenance, Drayage Service Corporation, *Oakland, Cal.*

PEARLSTONE, PAUL, sales manager, L. Pearlstone, *St. Louis.*

RASSBACH, ERICH, director of sales, Robert Bosch Actiengesellschaft, *Stuttgart, Germany.*

RISTINE, JOHN D., sales, Prest-O-Lite Co., Inc., *Indianapolis.*

RUHLING, B. A., foreman, Elkhart Rubber Works, *Elkhart, Ind.*

SCHINDLER, CORNEL, draftsman, Sikorsky Mfg. Corporation, *College Point, N. Y.*

SCHMIDT, ARTHUR R., draftsman, William Ganschow Co., *Chicago.*

SNYDER, ALPHA, assistant superintendent of motor transportation, Detroit Edison Co., *Detroit.*

UNDERWOOD, ARTHUR J., Society of Automotive Engineers, Inc., *New York City.*

VIBERG, E. R., chief engineer, Canadian Car & Foundry Co., Ltd., *Montreal, Canada.*

WHITE, LEO J., tool designer, Nash Motors Co., *Kenosha, Wis.*

WUERFEL, R. B., stress engineer, Chevrolet Motor Co., *Detroit.*

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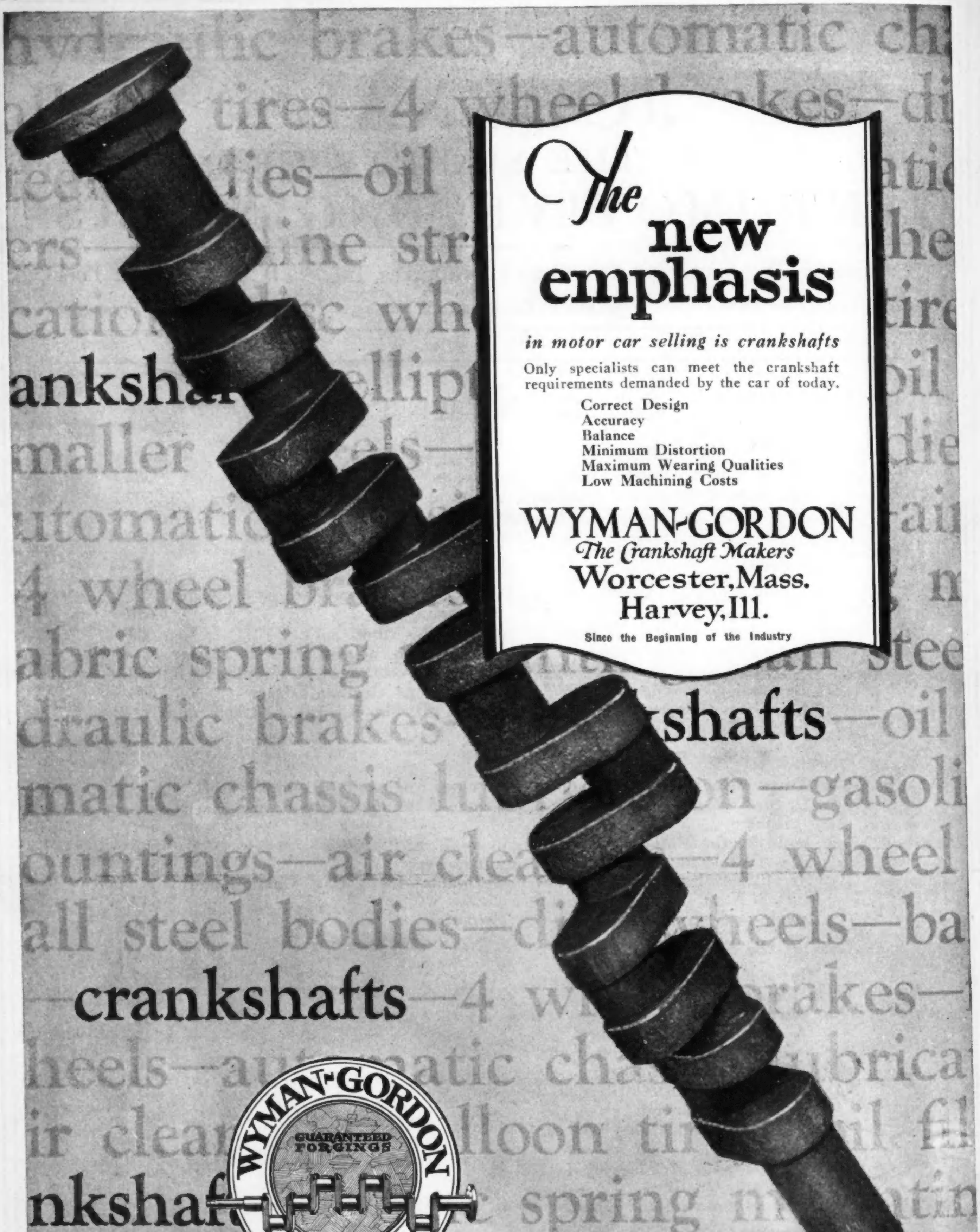
Vol. XX May, 1927 No. 5

CONTENTS



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